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A COMPUTERIZED AUTOMATIC MEASURING SYSTEM FOR CALIBRATION OF UN--ETC(U)

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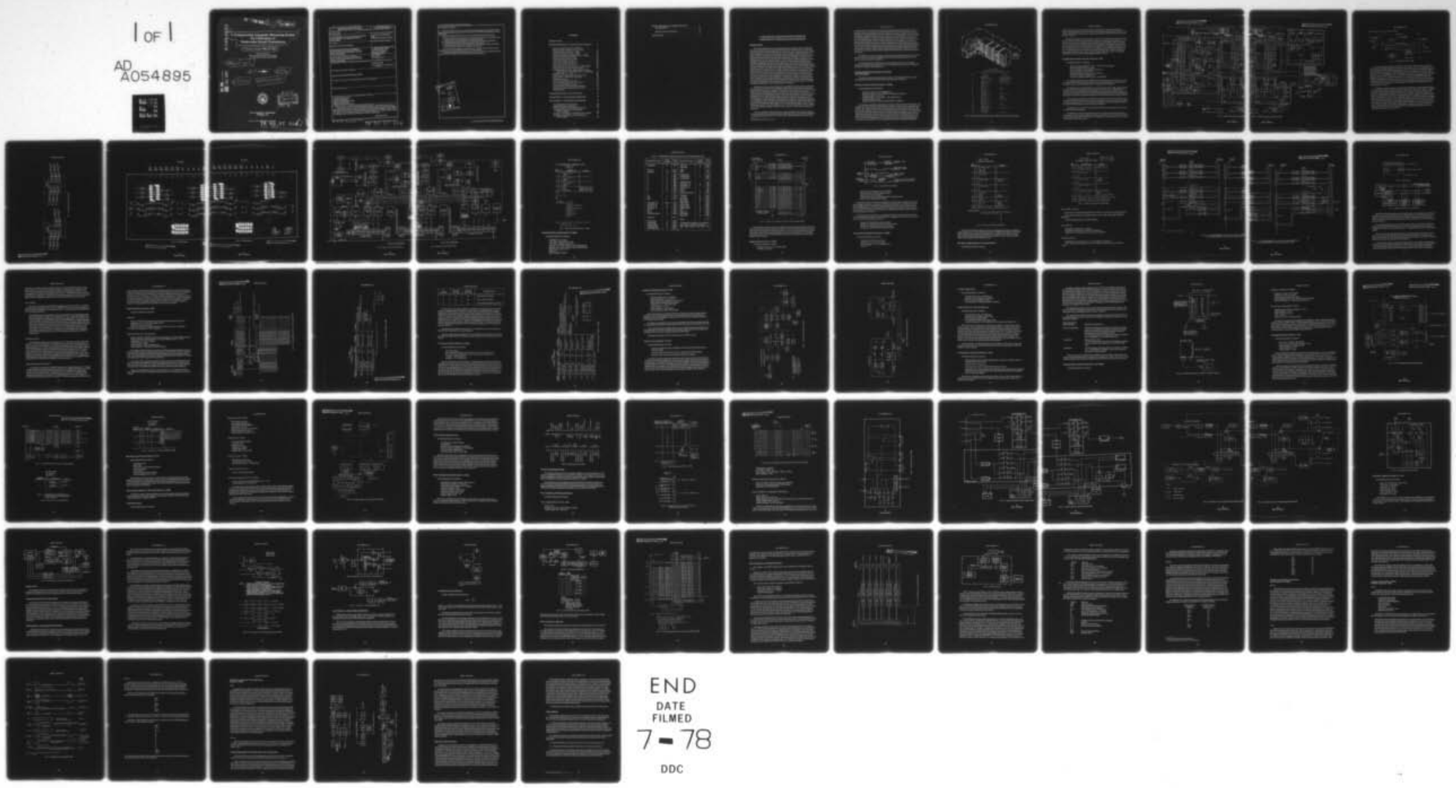

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# A Computerized Automatic Measuring System for Calibration of Underwater Sound Transducers.

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This project was conceived to develop the hardware phase of a computerized electronic system that would provide computer-controlled measurements of underwater device parameters in the Anechoic Tank Facility (ATF) of the Naval Research Laboratory's Underwater Sound Reference Division (USRD). This electronic system operates in conjunction with USRD's new PDP-11/45 computer, remotely located in a Computer Center, to control the ATF system by software programming.

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## 20. ABSTRACT (continued)

This system enables an operator to communicate control parameters to the computer in simple English-language statements and to monitor and control the received signal gating during the measurement process.

The major advantages realized with use of this computerized electronic system include:

- Real-time analyses of the test transducer to resolve problem areas while the transducer is suspended in the tank under the imposed environmental conditions,
- Recorded accurate and repeatable setup and control conditions for the measurements.
- Computerized data reduction that provides uniform report formats, and
- Accurate measurements, previously unattainable, of load impedance wherein the voltage or current waveforms powering the test transducer are distorted.

This system also has a completely manual mode or, via an integral acoustic coupler, may communicate over a commercial telephone line with any remote computer.

This hardware phase has been implemented in the ATF, and its effectiveness will continue to be analyzed relative to possible use in the other USRD measurement facilities.

## CONTENTS

# A COMPUTERIZED AUTOMATIC MEASURING SYSTEM FOR CALIBRATION OF UNDERWATER SOUND TRANSDUCERS

## INTRODUCTION

The Measurements Branch of the Underwater Sound Reference Division (USRD) of NRL makes measurements on underwater instruments and materials, both to verify their performance prior to and following their use in the Fleet and to obtain performance parameters in support of new unit R and D efforts. These measurements typically relate to dynamic electrical characteristics of underwater projectors during either a frequency sweep or physical rotational mode. Voltage and current amplitude, waveshape, and phase are of particular import. In addition, receiving hydrophone response voltage measurements are accomplished and may be combined with one or more of the projector characteristics as required by a particular test. Much of the measurement task involves comparison in the Anechoic Tank Facility (ATF) of new transducer parameters with standard transducers previously developed by the USRD. Historically, measurement data such as sensitivity curves or frequency response curves would be compared with a standard unit curve on a point-by-point basis, and a comparative curve or table relating the variations in performance characteristics of the two units would be developed by hand. Also, there have been occasions where upon reviewing the results and data from a test that it would be desirable to retest and vary one parameter such as temperature or pressure. The ability to set up under the same conditions was very limited. Similarly, it is frequently desirable to duplicate the frequency at various points of the spectrum following a frequency sweep. These things were not readily accomplished with the existing ATF system, and it was felt that a new system approach addressing these shortcomings would be worthwhile.

The system previously used incorporated a null-balance subsystem which determined the impedance of a transducer by measuring voltage (E) and current (I) and determining phase ($\phi$) by shifting in time a sample of the generator voltage waveform until the two waveforms canceled or provided a minimum, or null, on a scope viewed by the operator. A similar routine was repeated for the current waveform. The difference between the two was the phase shift. The major difficulty with such a measurement scheme was that both the voltage and current waveforms were distorted and, as a result, the operator was forced into a judgment posture looking for a minimal signal, a situation not adequately reproducible. Furthermore, there was little evidence that the null difference represents the phase difference of the fundamental frequencies of the two distorted waveforms. It was felt that a system that would do a Fourier transform on the two E&I analog signals, where a comparison of fundamental components could be made, would be a more accurate measurement technique.

The new computer-controlled system concept essentially has an operator communicate with the PDP-11/45 computer in simple English statements, calling up the program for the particular measurement to be conducted. The computer presents the operator with a

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set of questions to be answered such as frequency range and power level desired. The computer then takes the control, sets up the instruments to the stated conditions, measures responses from sampling digital voltmeters, makes the necessary calculations from the data, and displays the graph or table back to the operator at the measurement console. None of the problems that had vexed the old system are inherent in this computer-controlled system. The distasteful task of hand reduction of data is now gone. Since the computer can so rapidly make comparison of curves, a final sensitivity curve is available to the operator almost instantaneously, allowing on-the-spot experimentation with temperature, pressure, etc. while the transducer is still in the water under the exact conditions that developed the original curve. The system has alternately been designed to transmit analog data directly to the computers' analog to digital (A/D) converter for phase analysis by fast Fourier transform (FFT). In addition to the automatic features, the system has a complete manual mode of operation.

The USRD is currently considering converting all of its measurement systems from the old type to the new computer-controlled type, as the operational programs of the computer-controlled system are completed.

The program has thus far performed very successfully in the ATF. A continuing analysis of its effectiveness relative to its use in other measurement facilities will determine the extent to which it will be duplicated.

## SYSTEM COMPONENTS (GENERAL FEATURES AND OPERATION)

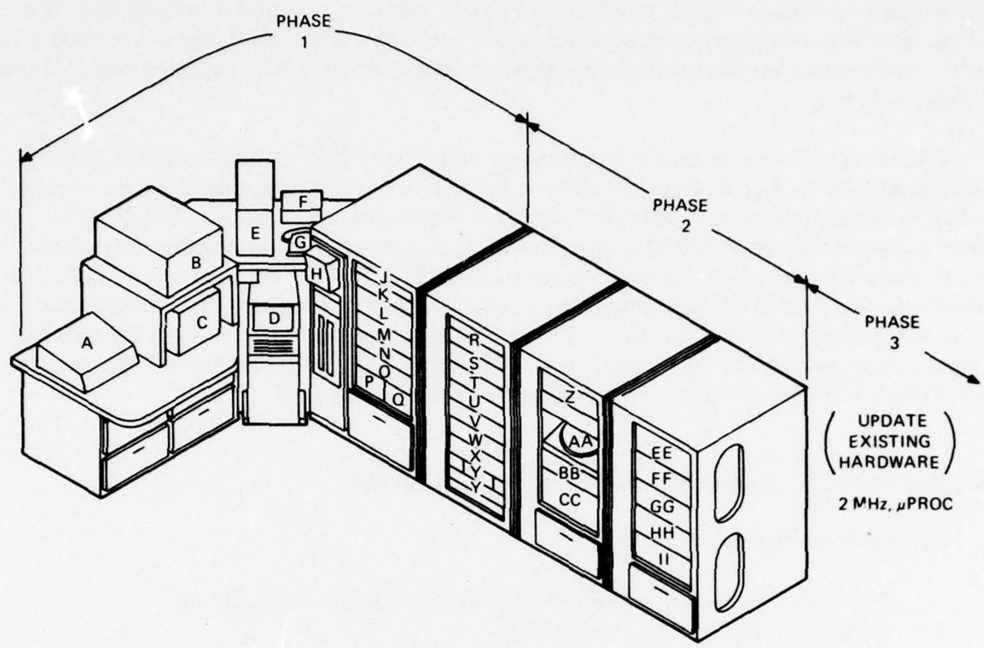
The major system components are shown in Fig. 1. The general description of each component and operational comments where appropriate are as follows:

### Frequency Synthesizer (Hewlett Packard No. 3330B)

General Specifications of Interest:

Frequency range: 0.1 to 13,000,999.9 Hz
Frequency steps: 10, 100, 1000 Hz or variable by computer
Frequency resolution: 0.1 Hz
Amplitude range: +13.44 dBm to -86.55 dBm (50 Ω)
Output impedance: 50 Ω
Harmonic distortion: Harmonics 60 dB down to 100 kHz

The frequency synthesizer selected has the option of manual or remote operation, and both are used. The manual mode is required for operation in the event of a computer-down situation. The remote mode is used by the computer to set up the selected frequency, frequency step, amplitude, time per step, sweep direction, and the number of frequency steps between start and stop frequencies and to command when each frequency step is taken. The synthesizer also provides a direct current (dc) output (0-10 V dc) proportional to the frequency range being swept. This dc output is used to drive the X-Y recorder and the Tektronix #613 (Tek-613) display in the X or frequency direction. Both alternating current (ac) and dc output signals are routed through the patch panel for alternate patching as




List of Materials

Computer Automatic Measuring System

(See 'System Components' of this Report for Detailed Descriptions)

| Item | Description | Remarks |
|---|---|---|
| A | x-y Plotter | |
| B | Hard Copy Unit | Via Terminal/Display |
| C | Large Screen Display | Primary Plot Display |
| C' | Hard Copy Control Switch | Copy Terminal or Display (see Dwg # E-1770) |
| D | Terminal | Computer Interface |
| E | Digital Oscilloscope | |
| F | Acoustic Coupler | Outside Communications |
| G | Telephone | |
| H | Intercom | |
| J | Waveform Monitors | |
| K | Counter | |
| L | H. P. Synthesizer | Primary |
| M | SDVM #1 | Primary |
| N | H. P. Scope | |
| O | Data Mover | |
| P | Tone Burst Generator | |
| Q | Attenuater | Primary Generator |
| R | Pre-Amp & Control | 2-Pcs. |
| S | Hyd. Panel | G. P. |
| T | H. P. Scope #2 | Secondary |
| U | SDVM #2 | Secondary |
| V | Monsanto Synthesizer | A/D Trigger Gen. |
| W | Data Mover #2 | |
| X | Phase Meter | Local - G. P. |
| Y | Pulse Gen | |
| Z | Shaft Angle Display | |
| A-A | Polar Plotter | 2-Pcs. |
| B-B | Filter | Programmable |
| C-C | Power Conditioner | |
| E-E | Impedance Panel | |
| F-F | Carriage Control Panel | Inside Tank Carriage |
| G-G | Transmit Panel | |
| H-H | Power Amp #1 | |
| I-I | Power Amp #2 | |
| y' | Krohn Hite Filter | Manually Set-up |

**Fig. 1 — Computer automatic measuring system (CAMS) for anechoic tank facility (ATF)**

required and shown on Fig. 2. In addition the synthesizer ac output is monitored by a counter and video-display monitor at all times. The computer command codes used to control the synthesizer are monitored on a light-emitting diode (LED) monitor panel as shown on Figs. 3, 4, and 5.

Encoding commands for the synthesizer come from the computer via the PDM 70 data mover as shown on Fig. 6. Communication between the computer and the data mover "J" module is serial American Standard Code for Information Interchange (ASCII). The data mover converts the serial ASCII commands to four-character octal parallel and strobes the four-character data out to the synthesizer *via* the PDM 70 "D" module upon receipt of an end-of-transmission (EOT) command from the computer. The PDM 70-to-synthesizer format is compatible with the synthesizer's new ASCII interface bus (or IEEE 75-488 Std.) scheme and is detailed in Fig. 7 using the HP programming codes in Table I. The synthesizer/PDM 70 interconnection wiring diagram is shown in Fig. 8.

**Sampling Digital Voltmeter (Scientific Atlanta No. 1166)**

General Specifications of Interest:

Input ac voltage range (log): +12.7 to -62.4 dB V autoranging
Frequency range: 10 Hz to 5 MHz
True rms measurement during gate period only
Input impedance: 1 MΩ, 22 pF
Max input voltage *via* range switching: 400 $V_{pp}$
Periodic integral rms measurement
Accuracy: 0.25 dB to 100 kHz, up to 1 dB @5 MHz

The Sampling Digital Voltmeter (SDVM) has both a manual and a remote mode, both of which are used in the system. An analog output is available and used to drive both the X-Y plotter and the Tek-613 display in the Y or response-level direction.

The SDVM has an external trigger mode used in this system, the trigger being supplied by the coherent toneburst generator interconnected as shown in Fig. 2. The SDVM is activated by the external trigger at the beginning of each toneburst. A variable delay is provided on the instrument for positioning the generated internal and variable sampling gate to the steady-state portion of the input bursted wave. This timing sequence is shown in Fig. 9.

The sample-gate output from the SDVM is monitored on the VU-Data display monitor to provide synchronization for the measurement waveform display and is also connected to the patch panel (see Fig. 2) for other convenient applications such as simultaneous display on the HP #1201B oscilloscope with the receive waveform.

The signal input comes from the patch panel where any system signal may be patched to the SDVM for measurement.

The SDVM has a reference signal input used in the system for periodic integral rms measurements of the received voltage waveform. This signal is used to provide zero crossover gating during small received, distorted, or noisy signals to correct for error due to one cycle uncertainty in rms measurements.

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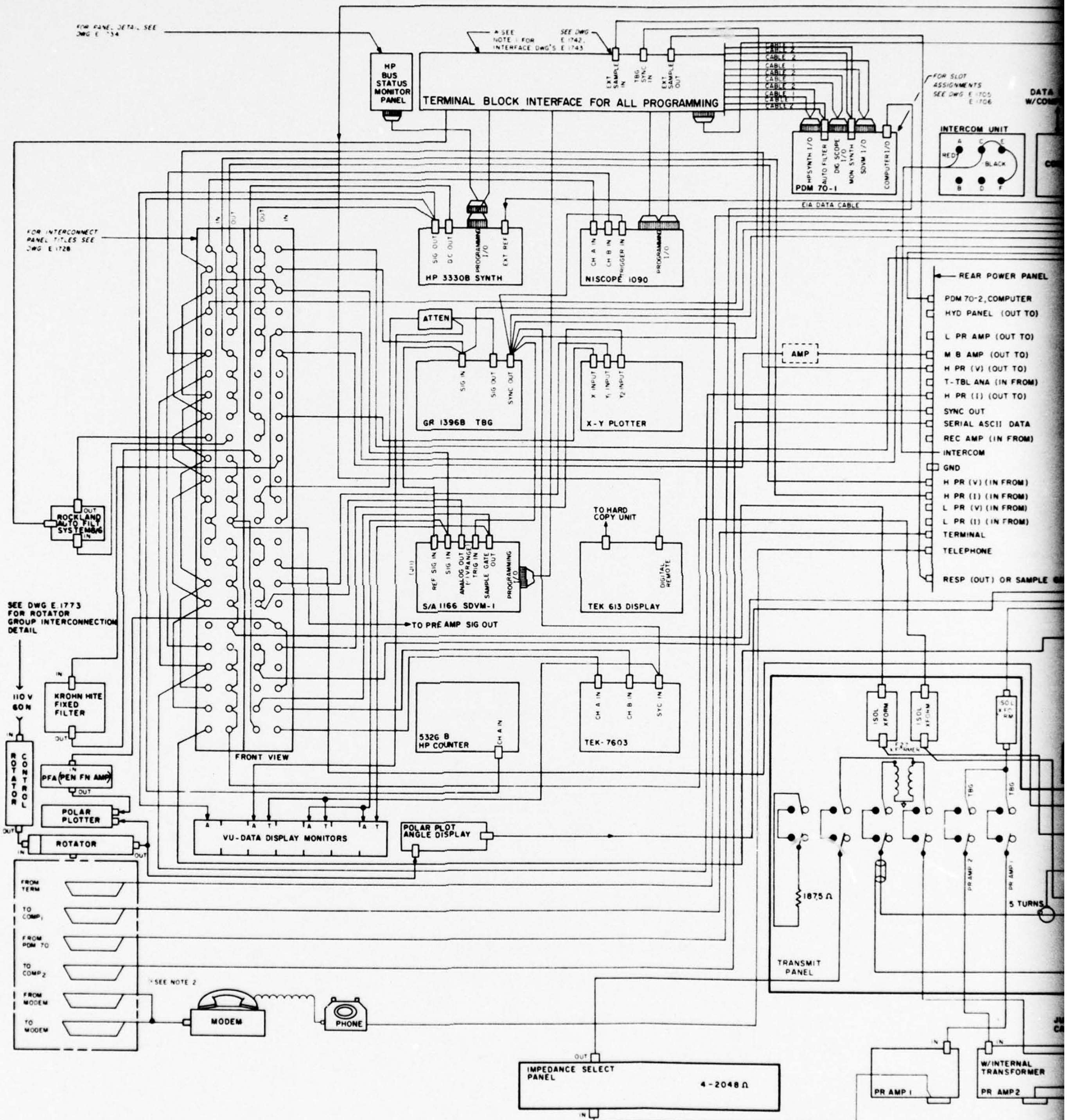

Fig. 2 — Console interconnection diagram CA

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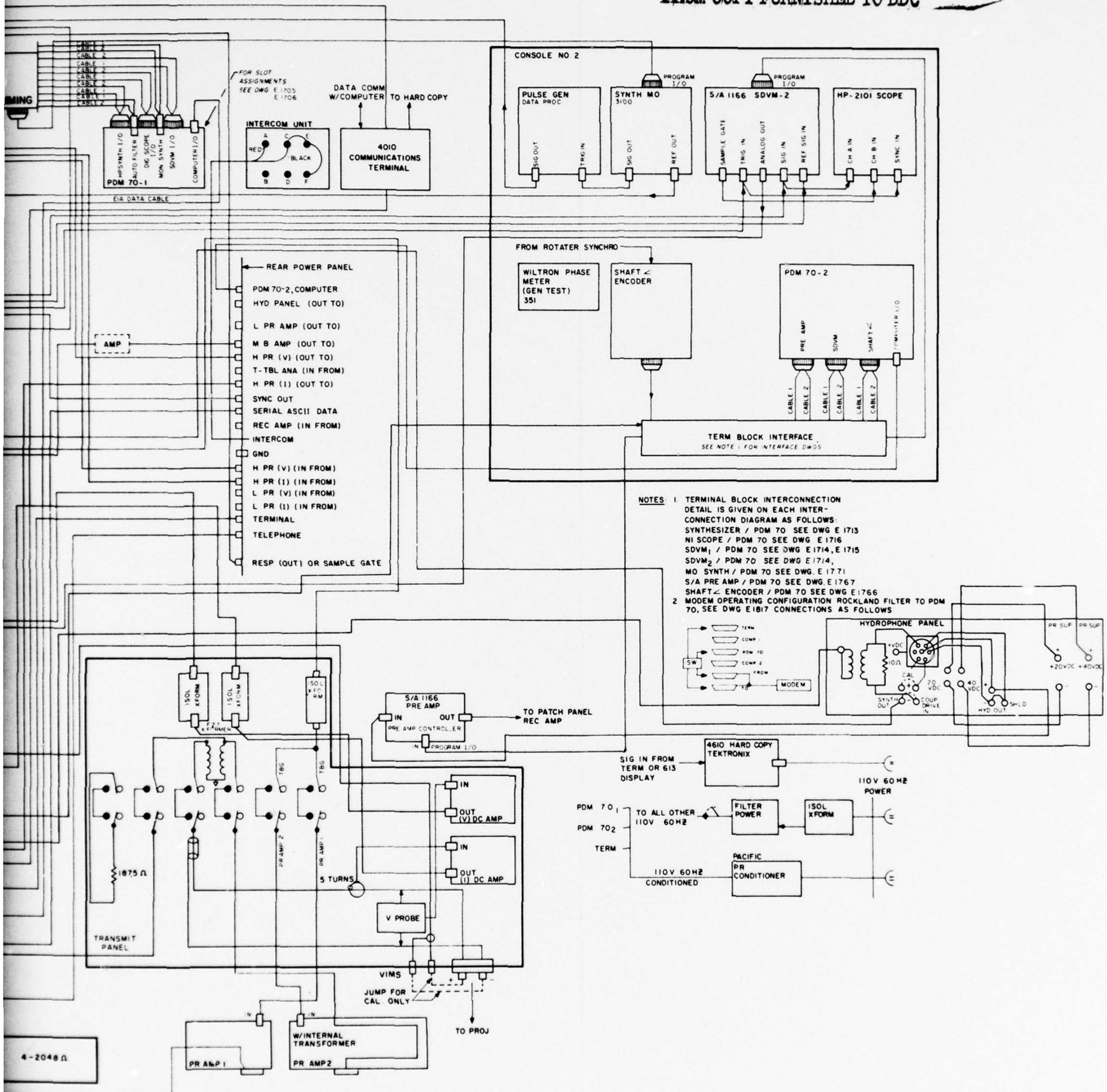


Fig. 2 — Console interconnection diagram CAMS

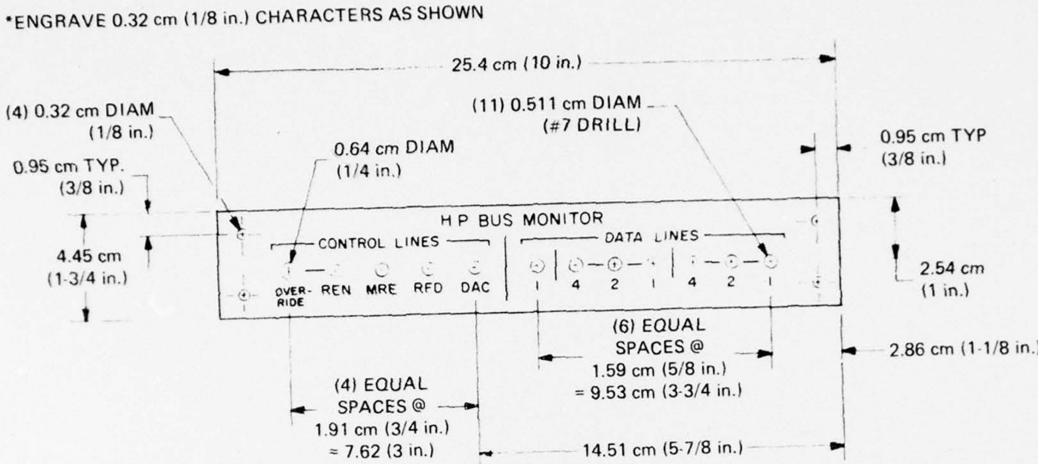


Fig. 3 — H.P. BUS monitor panel CAMS

Remote operation includes setup instructions from the computer which controls the dB offset of the digitally displayed measurement, the width control of the sample gate, the width multiplier, and the offset sign, as shown in Fig. 10. In addition, the digitally-displayed measurement data are available in BCD format at the rear programming connector. These data are sent to the computer *via* the PDM 70 data mover as shown in Fig. 6. In this case the PDM 70 receives the BCD data on its "D" module as 8 character parallel BCD (32 bits) and transfers the data to the computer through the "J" module in Serial ASCII format. The interface decoding data are shown in Fig. 11. The data transmitted are sign (one character), voltage digits (four characters), decimal position (one character), voltage range (one character), and log-linear mode selection (one character). The SDVM-PDM 70 interconnection wiring is shown in Fig. 12.

The SDVM as delivered required the following modification to assure positive readout of all measurements (Mod previously noted by ARL-Univ. of Texas). The SDVM as designed makes the measurement through analog circuits (S/A #1166 Instruction Manual p. 4-9), converts to digital binary, and places data onto an internal bus. The data are converted to BCD through a BIN/BCD converter and presented to both the display and the BCD output register. Previously, the strobe to the output BCD register occurred so late that the propagation time through the register was too long for maximum measurement period. The modification consists of tying one side of the input strobe AND gate to +5 V and the other side to the print command (J3 pin 18). The print command falls in coincidence with the completion of the sample gate and rises after completion of computation period (S/A #1166 Instruction Manual p. 2-8). This assures that the output BCD register will be strobed out only after the measurement is complete.

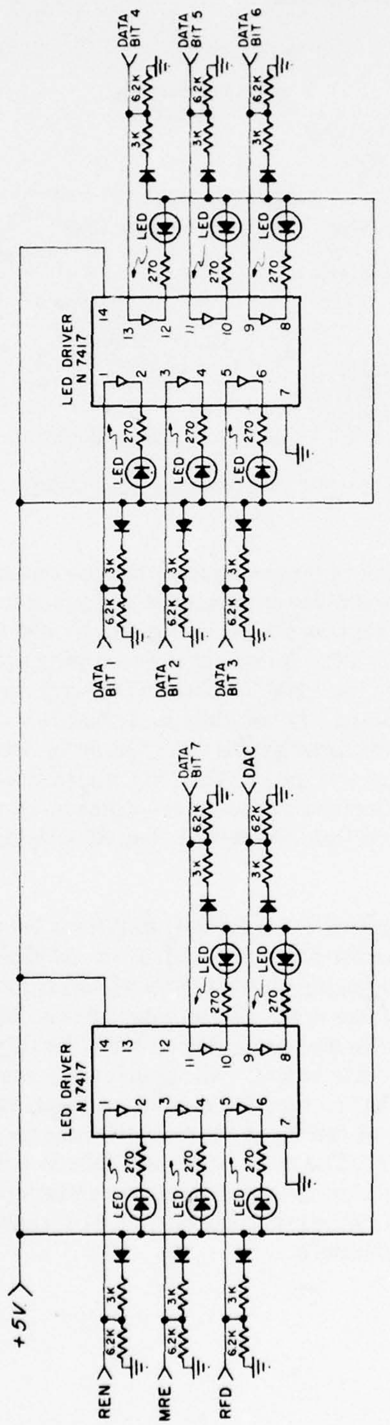


*Fig. 4* — **H.P. BUS monitor board CAMS**

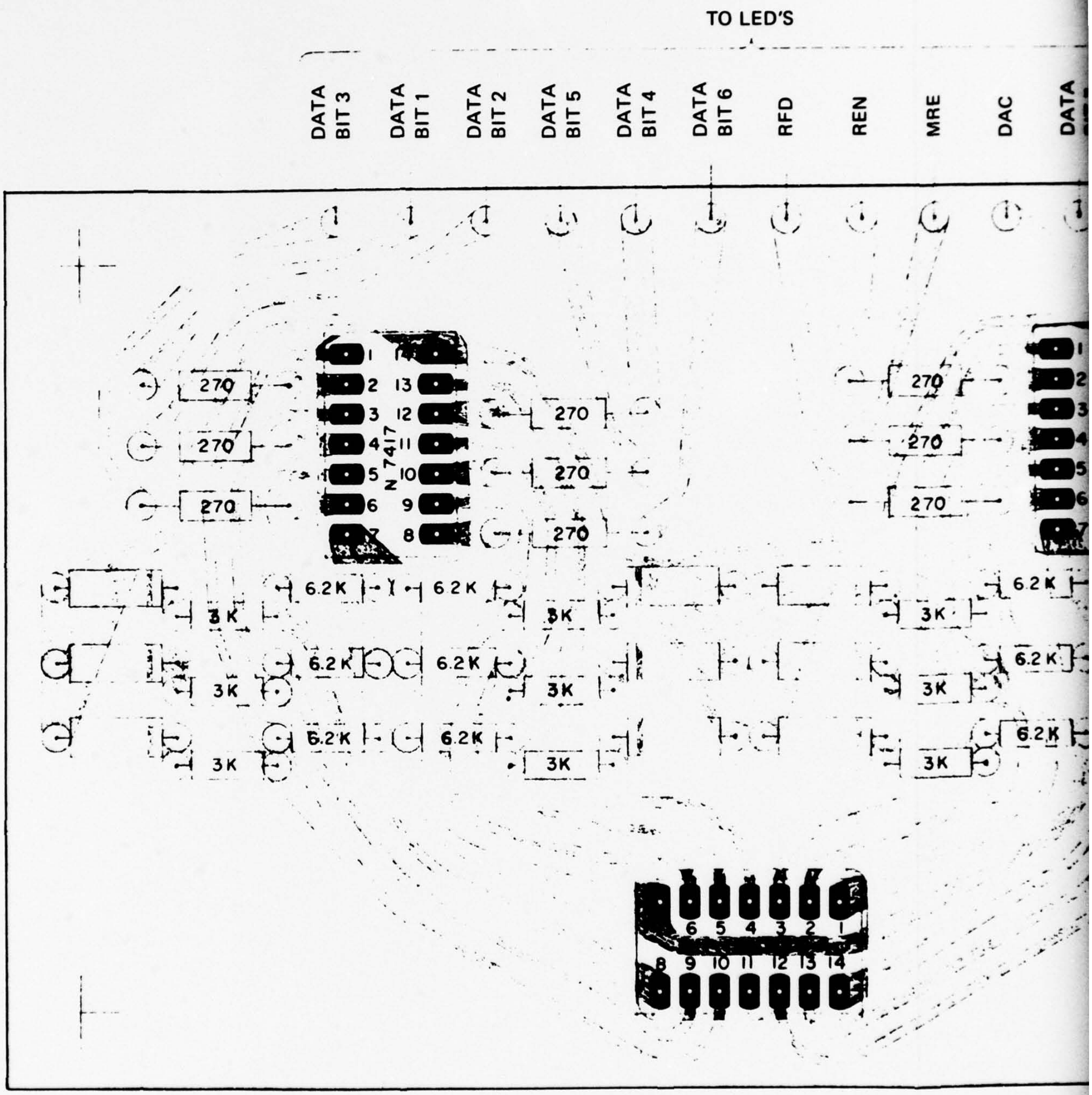


Fig. 5 — H.P. BUS monitor

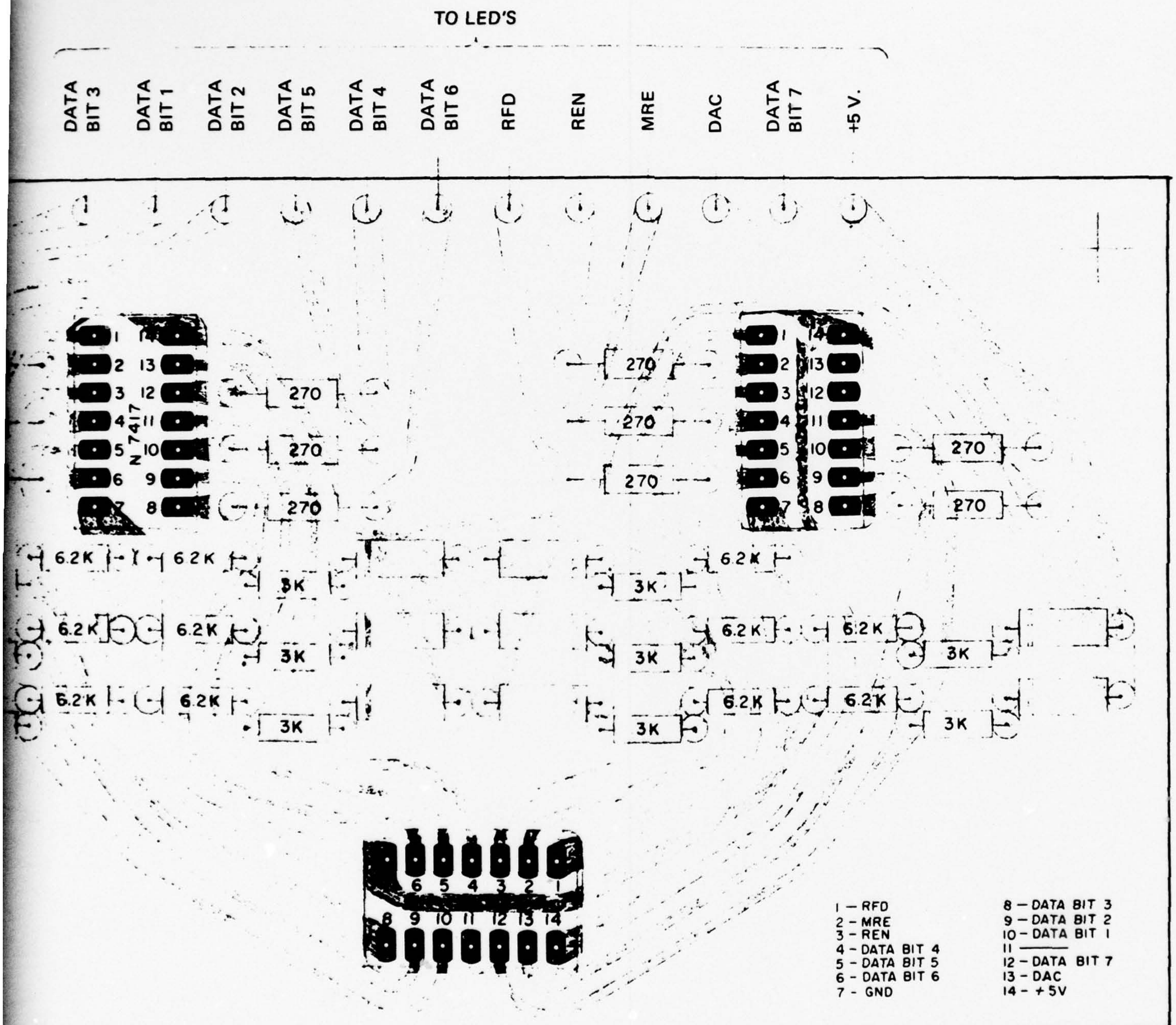


Fig. 5 — H.P. BUS monitor



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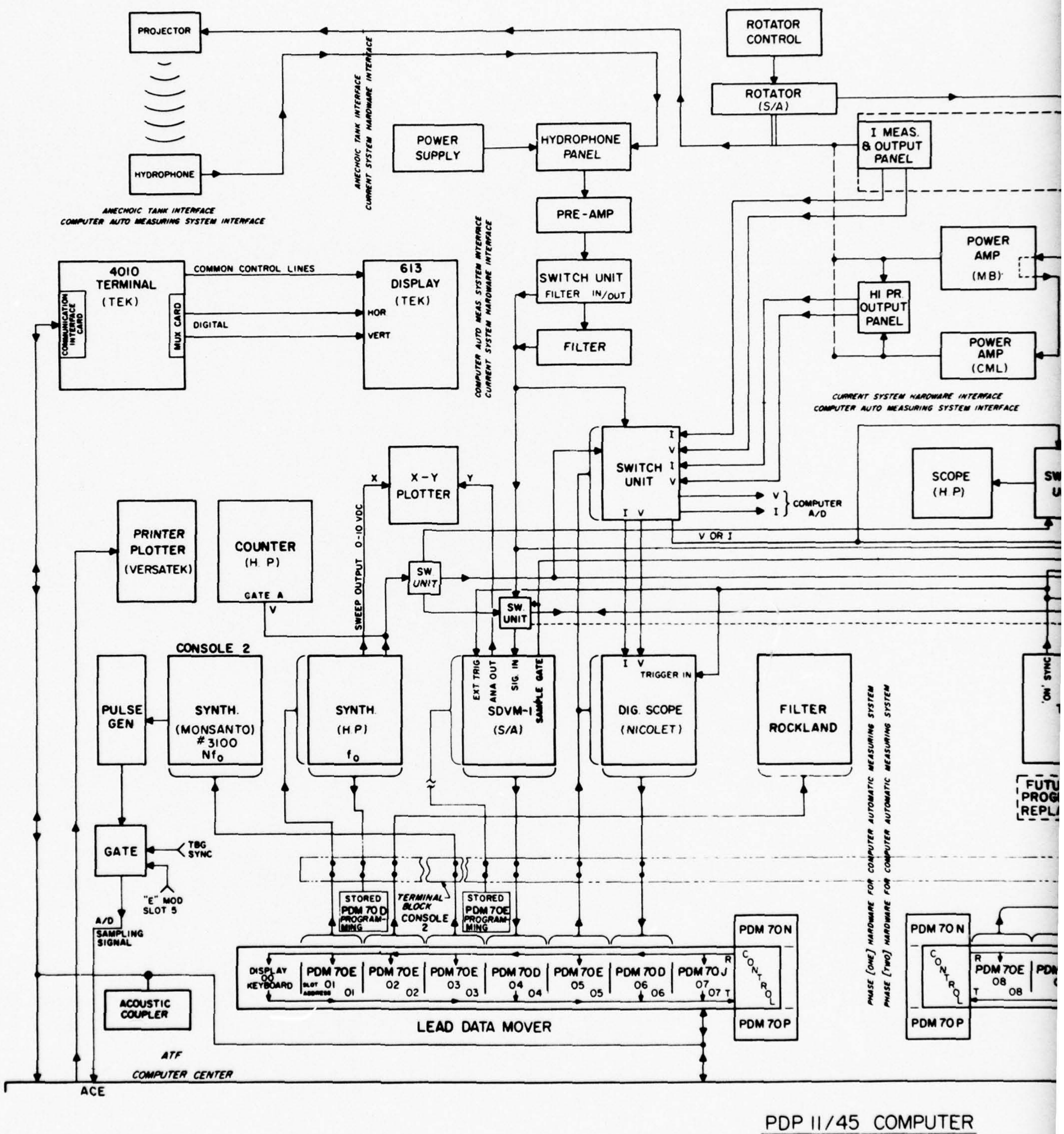



Fig. 6—Computer controlled ATF system

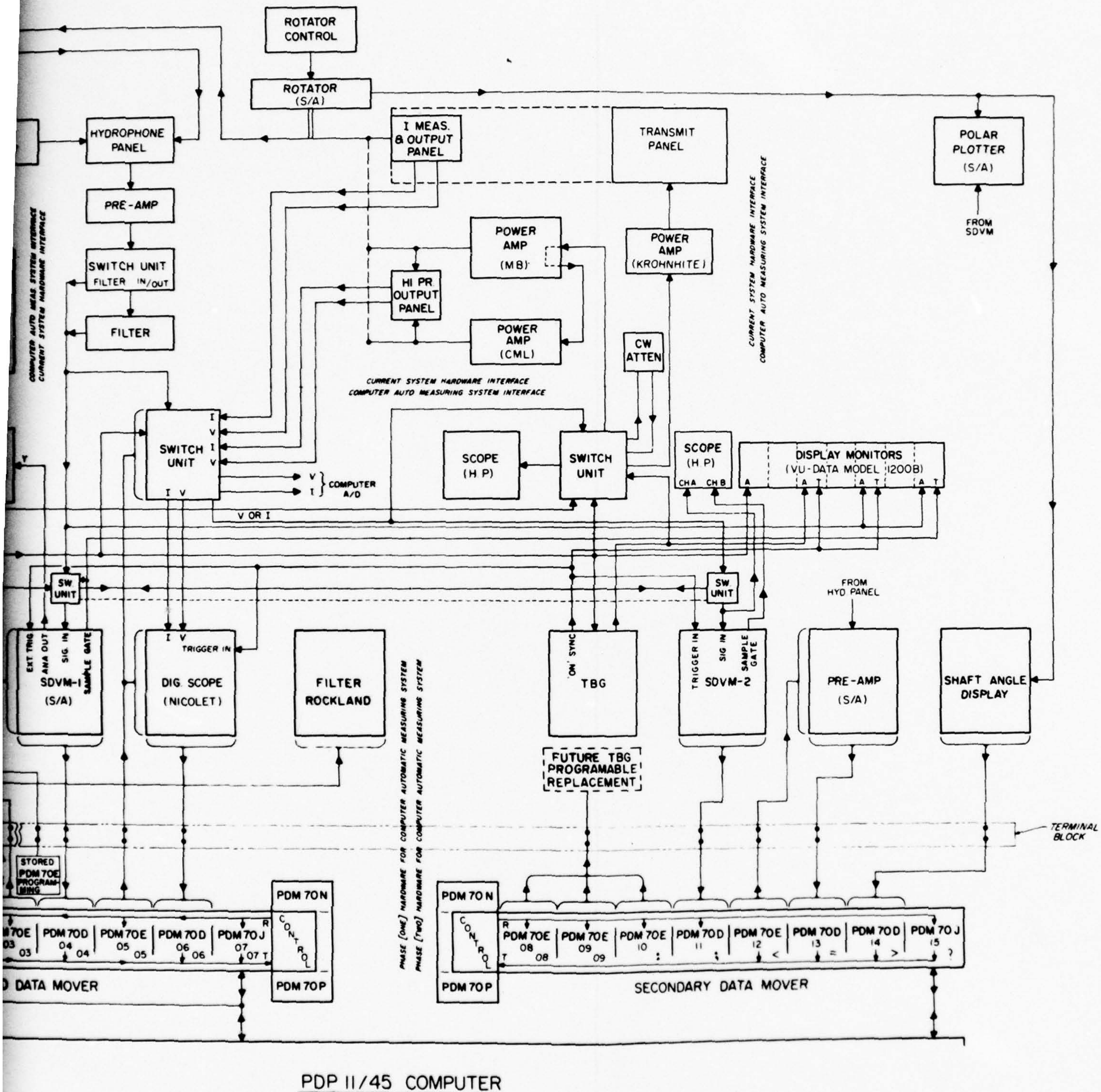



Fig. 6—Computer controlled ATF system

HP SYNTHESIZER - ADDRESS - 044
E-MODULE

| DIG. SEQ. | WT. | DIGIT NOMENCLATURE | REMARKS |
|---|---|---|---|
| 1 | 1 | MSD (Send 0-1)<br>FUNCTION<br>CODE | |
| 2 | 1<br>2<br>4 | 2nd (Send 0-7)<br>FUNCTION<br>CODE | |
| 3 | 1<br>2<br>4 | 3rd (Send 0-7)<br>FUNCTION<br>CODE | |
| 4 | 1<br>2<br>4 | MRE<br>REN<br>STEP INHIBIT | NORMAL STATE INACTIVE<br>NORMAL STATE ACTIVE<br>NORMAL STATE INACTIVE |
| 5 → 8 | NOT USED | | |

TYPICAL LOAD SEQUENCE:
1 REN CODE
2 EXECUTE
3 ADDRESS CODE, MRE CODE
4 EXECUTE
5 FUNCTION CODE, $\overline{\text{MRE}}$ CODE
6 EXECUTE
7 FUNCTION CODE
8 EXECUTE
9 FUNCTION CODE
10 EXECUTE
11 ETC

NOTES:
1 COMMANDS EXECUTED BY TRANSMITTING AN "EOT"
2 $\overline{\text{MRE}}$ CODE IS "0"
3 N B - REN CODE IS "0002"

Fig. 7 — Input encode-H.P. synthesizer — CAMS

## Toneburst Generator (General Radio No. 1396B)

General Specifications of Interest:

Mode Select: cw or pulse
"On" time: coherent 10 $\mu$s to 10 s
"Off" time: coherent 10 $\mu$s to 10 s
Descrete "on" cycles: coherent 1,2,4,8,16,32,64,128
Descrete "off" cycles: coherent 1,2,4,8,16,32,64,128
Trigger level: -10 to +10 V
Slope: + or -
Input impedance: 50 k$\Omega$

Table I — HP-3330A/B Frequency Synthesizer ASCII Programming Codes

| Key/Switch Position | ASCII Character | Octal Code | Key/Switch Position | ASCII Character | Octal Code |
|---|---|---|---|---|---|
| (Address)* | $ | 044 | Ampl (A) | N | 1160 |
| | | | Ampl Step | O | 1170 |
| Freq (F) | L | 1140 | +dBm | ; | 073 |
| Freq Step | M | 1150 | dBm | < | 074 |
| 0 | 0 | 060 | Leveling Off | ← | 1370 |
| 1 | 1 | 061 | Leveling Slow | ] | 1350 |
| 2 | 2 | 062 | Leveling Fast | ↑ | 1360 |
| 3 | 3 | 063 | | | |
| 4 | 4 | 064 | Ampl Step ×10 | " | 042 |
| 5 | 5 | 065 | Ampl Step ÷10 | # | 043 |
| 6 | 6 | 066 | Ampl Step ×2 | & | 046 |
| 7 | 7 | 067 | Ampl Step ÷2 | ' | 047 |
| 8 | 8 | 070 | Ampl ↑ | ) | 051 |
| 9 | 9 | 071 | Ampl ↓ | ( | 050 |
| . | : | 072 | Ampl Sweep Mode | C | 1030 |
| Hz | = | 075 | 1 ms/Step | P | 1200 |
| kHz | > | 076 | 3 ms/Step | Q | 1210 |
| MHz | ? | 077 | 10 ms/Step | R | 1220 |
| | | | 30 ms/Step | S | 1230 |
| Freq Step ×10 | Space | 040 | 100 ms/Step | T | 1240 |
| Freq Step ÷10 | ! | 041 | 300 ms/Step | U | 1250 |
| Freq Step ×2 | $ | 044 | 1000 ms/Step | V | 1260 |
| Freq Step ÷2 | % | 045 | 3000 ms/Step | W | 1270 |
| Freq ↑ | * | 052 | Stop | X | 1300 |
| Freq ↓ | + | 053 | Start Cont | Y | 1310 |
| Freq Sweep Mode | B | 1020 | Start Single | [ | 1330 |
| | | | First Point | Z | 1320 |
| Sweep Up | I | 1110 | | | |
| | | | Clear* | ? | 077 |
| Sweep Down | J | 1100 | | | |
| Sweep Both | K | 1130 | | | |
| 10 Steps/SWP | D | 1040 | | | |
| 100 Steps/SWP | E | 1050 | | | |
| 1000 Steps/SWP | F | 1070 | | | |

*Address and clear must be accompanied by an MRE. On 3260A Card Reader MRE = 200 (Address = 244, Clear = 277).

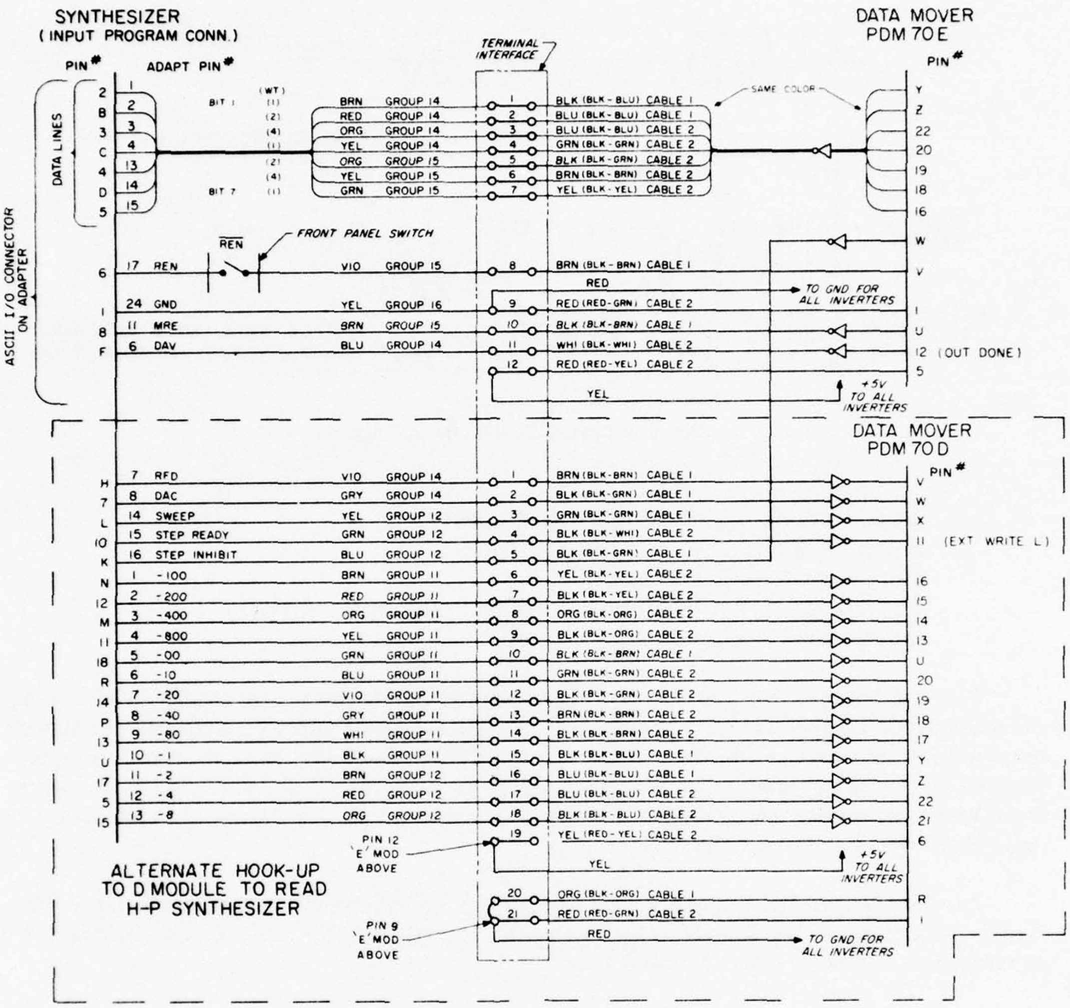



Fig. 8 — Data mover to synthesizer interface connection diagram CAMS

The toneburst generator receives a cw signal from the frequency synthesizer and either passes it along in the cw mode or gates the signal on and off in a coherent fashion in accordance with the manually-selected front-panel controls. The toneburst generator also provides a sync pulse output which is used throughout the system for timing (see Fig. 2). Relationship of the sync pulse to the bursted waveform is shown in Fig. 13. There is no sync pulse available in the cw mode.

### Display Monitor (VU Data No. 1200)

General Specifications of Interest:

Frequency response: dc to 5 MHz (3 dB)
Coupling: ac, dc, gnd

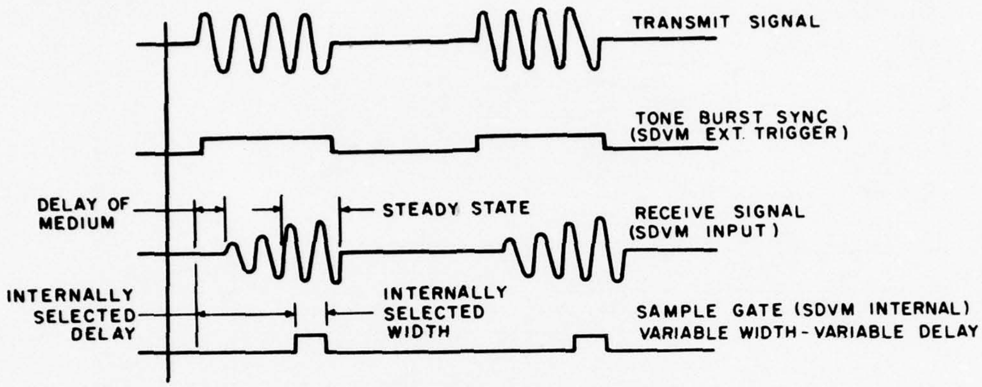



Fig. 9 — Typical SDVM timing diagram

Sensitivity: 50 mV/division to 10 V/division
Input impedance: 1 MΩ w/parallel 100 pF
Time base: 2 to 20 ms/division
Trigger: Mode, source, slope controlled by internal switches
Inputs: Two (switchable) per display.

This display monitor consists of a mainframe with integral power supply as well as signal and trigger input ports. Any number of descrete monitors (up to a maximum of seven) may be plugged into the mainframe and operated simultaneously. Each monitor contains its own display adjustment controls either on the front panel (exposed or under flip open front panel) or on the circuit board internal to the display plug-in. There are four monitors used in the system at this time.

The function of the monitors is to provide the operators with continuous status relative to measurement waveforms as well as signal flow diagnostics. Each of the four monitors provides the following display waveforms:

Monitor #1: Synthesizer output waveform
Monitor #2: Toneburst generator output waveform
Monitor #3: SDVM (receive) input waveform
Monitor #4: Signal in SDVM measurement gate

**Counter/Timer/DVM (Hewlett Packard No. 5326B)**

General Specifications of Interest:

Range: 0 to 50 MHz (dc coupled)
Sensitivity: 0.1 V sine, 0.3 V pulse
Input impedance: 1 MΩ w/parallel 25 pF
Slope: + or –

S/A SDVM
E-MODULE (CONTROL)

| DIG. SEQ | WT. | | REMARKS |
|---|---|---|---|
| 1 | 1 | HUNDREDS OFFSET | |
| | 2 | " " | |
| | 4 | NOT USED | |
| | 8 | NOT USED | |
| 2 | 1 | TENS OFFSET | |
| | 2 | " " | |
| | 4 | " " | |
| | 8 | " " | |
| 3 | 1 | UNITS OFFSET | dB OFFSET CONTROL |
| | 2 | " " | |
| | 4 | " " | |
| | 8 | " " | |
| 4 | 1 | TENTHS OFFSET | |
| | 2 | " " | |
| | 4 | " " | |
| | 8 | " " | |
| 5 | 1 | 1 sec WIDTH | |
| | 2 | 100 ms " | |
| | 4 | 10 ms " | WIDTH CONTROL |
| | 8 | 1 ms " | |
| 6 | 1 | 100 μs " | |
| | 2 | 10 μs " | |
| 7 | 1 | X 1 MULTI | WIDTH MULTI CONTROL |
| | 2 | X 2 " | |
| | 4 | X 5 " | |
| 8 | 1 | + OR − (1 OR 0) | OFFSET SIGN |

PROGRAM EXAMPLE:

TO SET UP A 1 ms SAMPLE GATE WIDTH, PROGRAM INTO THE PDM 70 DIGITS AS FOLLOWS:

0
0
0
0
8
0
1
0

Fig. 10 — Character encoding to SDVM CAMS

The counter provides the primary function of displaying the frequency synthesizer output frequency at all times. (The synthesizer has an integral LED display of frequency which is visible only on selected operating modes.) In addition, the counter serves as a basic off-line general measuring instrument for measuring the period of various system pulses and as a general system diagnostic DVM.

### Data Mover (Digital Equipment Corp. Model PDM 70)

General Specifications of Interest:

S/A SDVM
D-MODULE (RECEIVE DATA)

| ADDRESS | UNIT |
|---|---|
| SLOT 4 | SDVM 1 |
| SLOT = | SDVM 2 |

| DIG. SEQ. | WT. | DIGIT NOMENCLATURE | REMARKS |
|---|---|---|---|
| 1 | 1 | - OR + ( > OR ? ) | VOLTAGE SIGN |
| 2 | 1<br>2 | HUNDREDS VOLTAGE<br>" " | DISPLAY VOLTAGE DIGITS |
| 3 | 1<br>2<br>4<br>8 | TENS VOLTAGE<br>" "<br>" "<br>" " | |
| 4 | 1<br>2<br>4<br>8 | UNITS VOLTAGE<br>" "<br>" "<br>" " | |
| 5 | 1<br>2<br>4<br>8 | TENTHS VOLTAGE<br>" "<br>" "<br>" " | |
| 6 | 1<br>2 | 0 = DECIMAL 0 BACK<br>1 = " 1 "<br>2 = " 2 "<br>3 = " 3 " | DECIMAL POSITION DIGIT<br>EXAMPLE<br>0234311 INDICATES 0.234. VOLTS |
| 7 | 1 | mv OR v (0 OR 1) | VOLTAGE RANGE ("0" ON LOG MODE) |
| 8 | 1 | LOG OR LIN (6 OR 7) | LOG-LIN READOUT MODE |

Fig. 11 — Character decoding from SDVM CAMS

*System* (Refer to Fig. 6)

Data Format: Standard Serial ASCII Code, Format of 7 bits plus one unused parity bit

Speed: 39.6 kilobaud with switchable options of 110, 1200, 1800, 2400, 4800, and 9600 baud

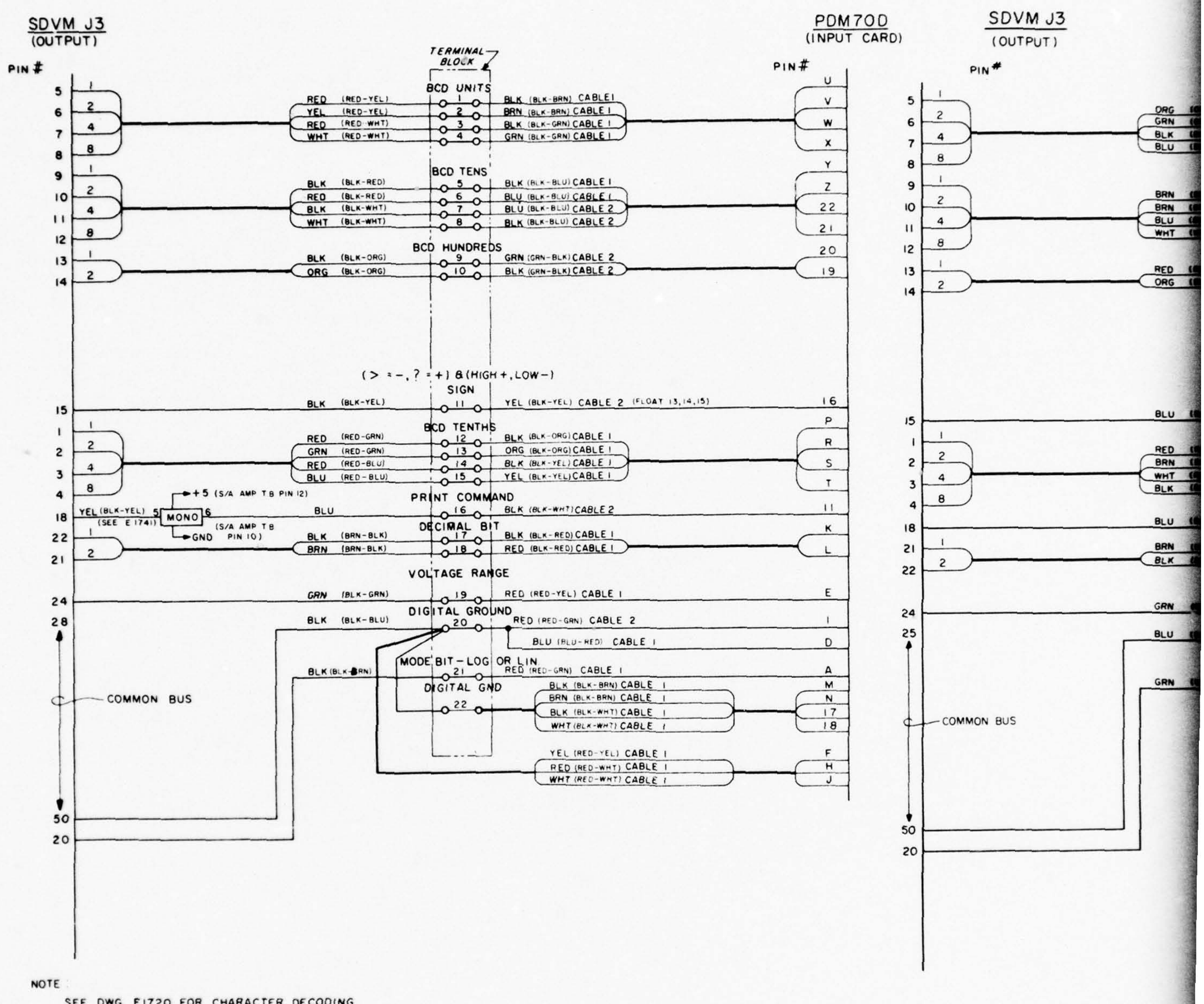
Internal Program Storage: 64 ASCII characters

*Source Module*

BCD/Binary: 8 BCD digits or 32 bits
Keyboard: 30 characters; 16 keyboard w/shift key
Serial I/O: EIA compatible with modem control facilities

*Destination Module*

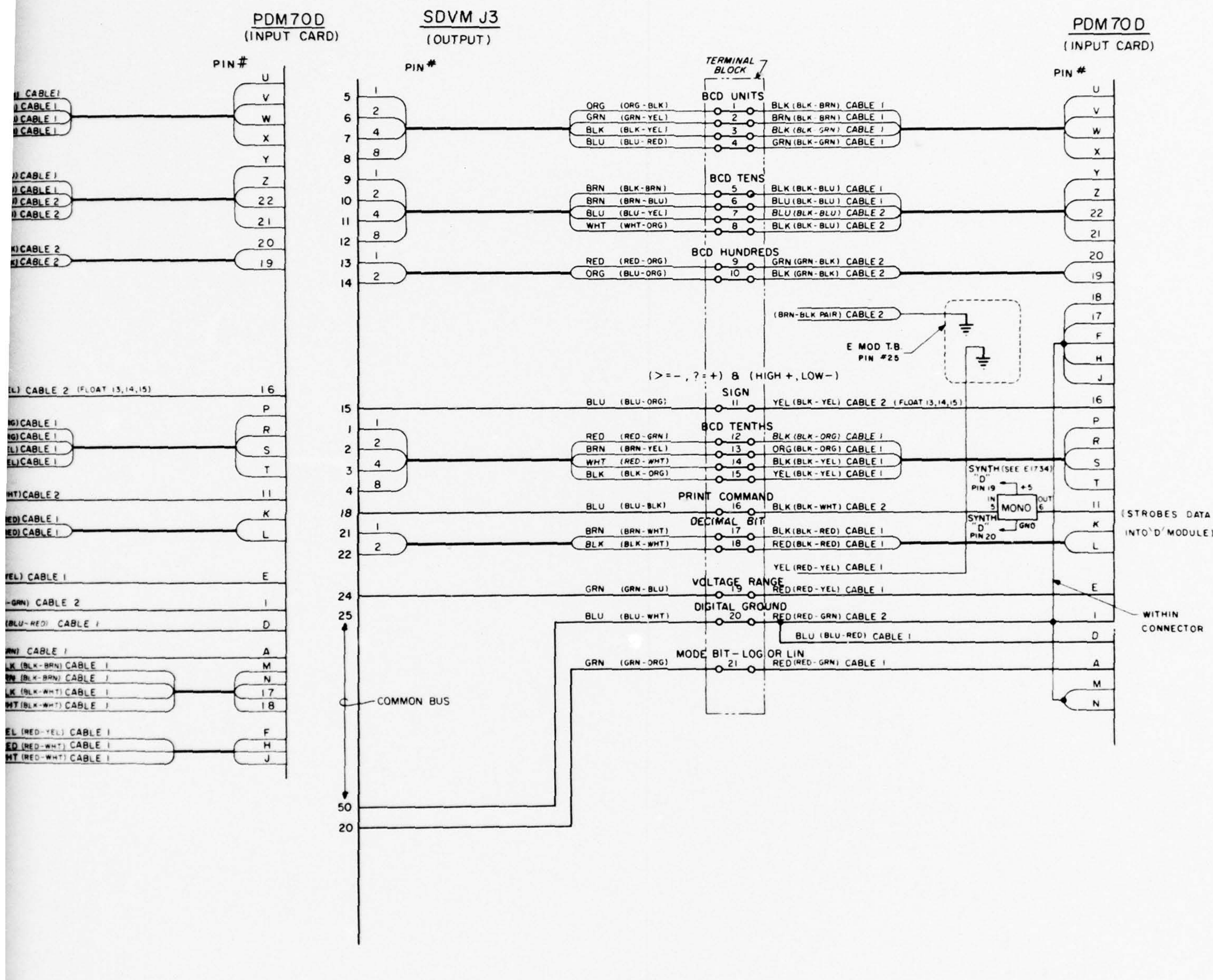
BCD/Binary: Linear 32 position 5 × 7 Dot Matrix, 64 characters
Other modules are available for use with the PDM 70; however, they are not used herein.




NOTE:
SEE DWG E1720 FOR CHARACTER DECODING

(a)

Fig. 12 — (a) 1166 $SDVM_2$/PDM $70_2$ interconnection diagram CAMS,
(b) 1166 $SDVM_1$/PDM $70_1$ interconnection diagram CAMS




(b)

Fig. 12 — (a) 1166 $SDVM_2/PDM\ 70_2$ interconnection diagram CAMS, and (b) 1166 $SDVM_1/PDM\ 70_1$ interconnection diagram CAMS

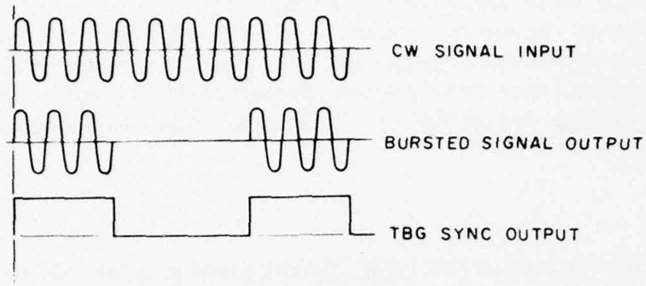



Fig. 13 — System timing

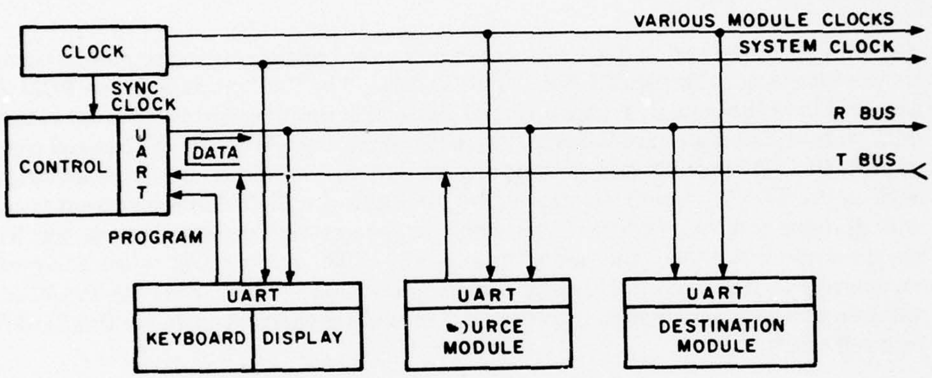



Fig. 14 — DEC PDM 70 data mover block diagram

The PDM 70 basically operates on an internal common bus configuration consisting of a transmit (T) and receive (R) common bus. Communication to and from each bus is controlled by a control module which itself is controlled by program inputs from either the PDM 70 keyboard or from any communications source module placed on the transmit bus as shown in Fig. 14.

Two separate PDM 70 units are used in the system. Only one unit has the keyboard, display, and associated modules shown in Fig. 14. The unit without keyboard control is programmed entirely by the computer thru the "J" communication (source or destination) module.

The common bus concept permits any type of module (source or destination) to be placed in any of the eight module slot positions within the PDM 70. This feature yields maximum flexibility for controlling instrumentation via the destination modules or reading instrument measurement data via the source modules.

Communication with the computer takes place thru the "J" module in serial ASCII format at a speed of 1200 baud (operation at 2400 baud is under further investigation). The "J" module transmits control information to the control module which in turn places on-line any program selected source or destination module to be utilized in a particular

operation. For example, it may be desired to have the computer speak directly to the frequency synthesizer to command a particular frequency. In this case the computer *via* the "J" module commands the control module to place the "E" destination module on-line. Subsequently, the computer may speak directly to the "E" module and thereby to the interfaced frequency synthesizer. Conversely the computer may ask that a "D" source module be placed on-line for subsequent reading of a "D" module interfaced measurement device.

### *Source Module*

The source module used in this PDM 70 configuration is the "D" module. It is used to take data from a measuring device, such as the SDVM, and convert the data on command to serial format for transmission to the computer *via* the "J" module. Data are transferred into the "D" module as follows:

> The SDVM has several voltage digits encoded and available at its programming connector simultaneously in parallel 8-4-2-1 BCD form. The "D" module of the PDM 70 will accept 32 parallel bits or 8 characters of BCD data simultaneously. It is necessary then only to interface each parallel BCD character from the SDVM to the desired significant digit of the "D" module and provide the desired strobe-in command. Measuring devices such as the SDVM provide strobes at the time that the SDVM measurement is complete and all digits resulting therewith are stable at the external program connector. This strobe mode is the "external write" mode in the "D" module and is the mode used exclusively in this system. However, an alternate mode is available with the PDM 70 wherein the data are strobed into the "D" module asynchronously *via* the PDM 70 internal clock.

### *Destination Module*

The destination module used in this system is the "E" module. It converts serial data from the "R" bus to parallel data on the output of the module. The module provides up to 32 bits or 8 characters of parallel 8-4-2-1 BCD data simultaneously at the module output. Serial characters on the "R" bus are sequentially decoded and stored in accordance with the most-to-least significant digits and registered at the output terminals of the "E" module. Upon completion of the data transfer to the module output terminals, the "E" module generates an "out-done" pulse which is used by external measurement devices, such as the frequency synthesizer, to strobe-in commands from the computer. The "E" module essentially converts the serial ASCII commands from the "R" bus to the 32-bit parallel binary or 8-character 8-4-2-1 BCD format required by the instrumentation.

### *PDM 70 Internal System Concepts*

A command is entered into the PDM 70 either by the integral keyboard or "J" module computer interface. The desired command is prefaced by a program executed by the control to put on-line the desired module for communication. For example, the program may specify any one of the several "E" modules to get on-line with the "J" module for subsequent commands from the computer. In a similar fashion, any one of the several "D" modules may be specified to get on-line with the "J" module to transmit measurement data

to the computer. This process requires that the program instruction to the control module spell out the address of both source and destination modules to be interconnected for direct subsequent communications. Furthermore, a complete program sequence (such as "P" module connect to "E" module, "P" module transmit a command, "E" module connect to "J" module and transmit measurement data to the computer) may be stored in the program module for execution each time a simple "EOT" command is received from the computer. This internal PDM 70 program storage significantly cuts down the control characters required for transmission from the computer to execute a measurement.

**Digital Oscilloscope (Nicolet No. 1090)**

General Specifications of Interest:

*Mainframe*

Memory: 4096, 12-bit words (memory may be used in quarters, halves or all)
Expansion: 2, 4, 8, 16, 32, 64 of triggered data
Erase: Manual erase of memory
Digital I/O: 12-bit TTL binary coding of each stored word (may be interfaced w/recorder and redisplayed on scope optionally)

*Plug-In Model 93 with C & D Amplifiers*

Modes: Real-time (circulating), hold last triggered sample, hold next triggered sample
Trigger: Internal, external, recurrent w or w/o midsignal ($\pm 0.25$ V to $\pm 5$ V)
Input ranges: $\pm 1\ V_{pp}$ to $\pm 400\ V_{pp}$
DC offset: 90% of range
Input impedance: 1 MΩ w/parallel 47 pF
Input frequency: 1 MHz max @ Nyquist sampling

The digital oscilloscope receives two inputs (2-channels analog), samples the data at a 2-MHz rate, and stores the resultant sample in memory when the "Store" button is pressed. The stored data are displayed along with a digital display of amplitude and time domain data. Upon depressing the "I/O Execute" button, the digital data are available at the output rear connector as 12-bit words for each stored point.

The control of the scope may be either manual or remote. Fig. 15 describes the interface for remote control operation of the scope. It will be noted that the controlling functions come directly from the "E" module of the PDM 70 which in turn is under control of the computer. Fig. 16 defines the detailed encoding to affect the desired operations.

Figure 15 demonstrates that when a control character (2 bits) appears on PDM 70 "E" module Pins 15 and 16, the digital scope is placed into one of several output modes as follows:

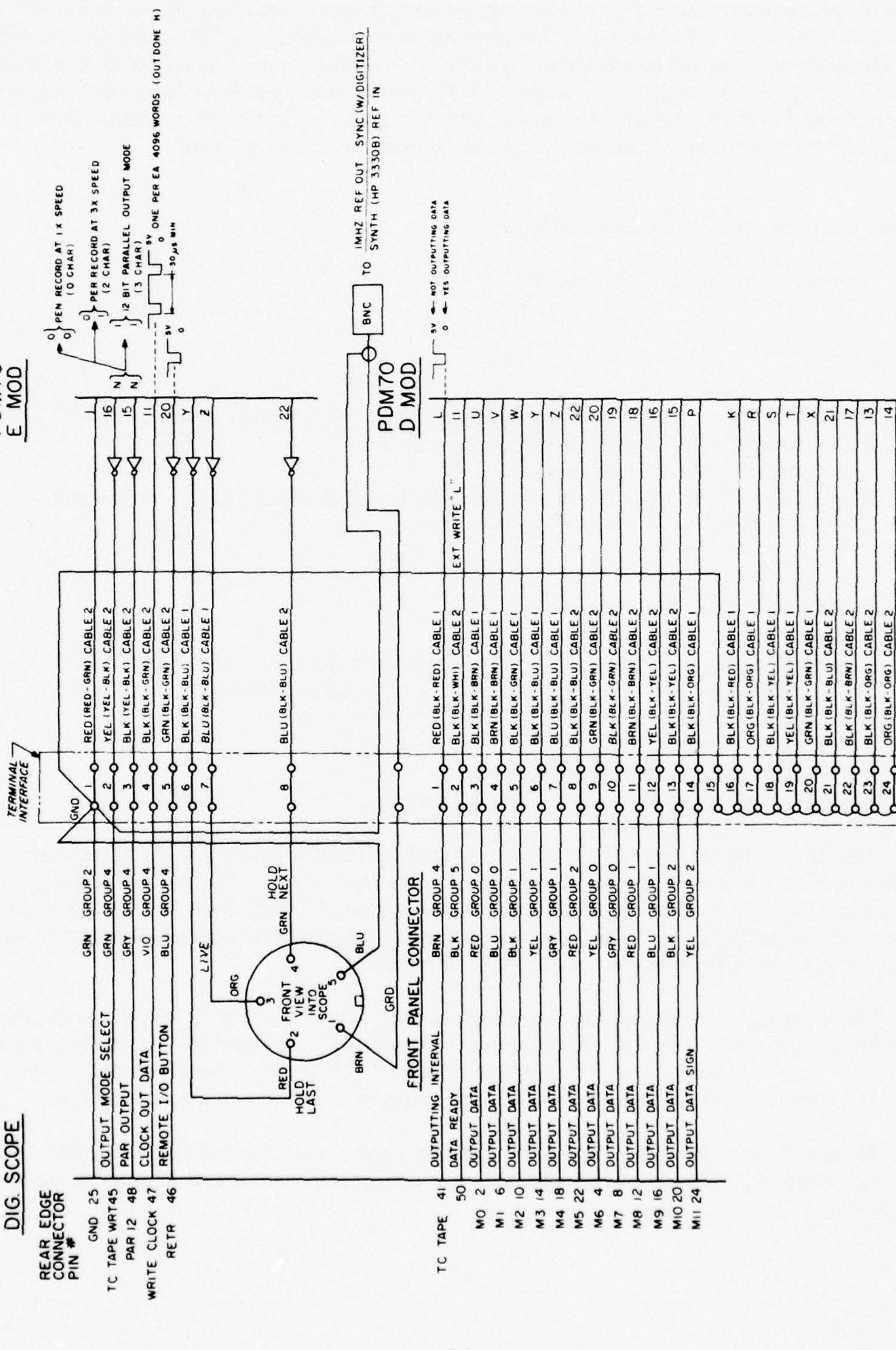



Fig. 15 — NI scope/PDM 70 interconnection diagram CAMS

## NI SCOPE
### ( E-MODULE INTERFACE )

| PDM 70 INPUT DIGITS | WT. | SCOPE INTERFACE BITS | INPUT DIG. MAKE-UP | PDM 70 INPUT ENCODE | REMARKS | |
|---|---|---|---|---|---|---|
| 1 (MSD) | 1<br>2<br>4<br>8 | OUTPUT MODE SELECT<br>" " "<br>NOT USED<br>NOT USED | 1 (MSD) | SCOPE OUTPUT MODE<br>PARALLEL OUT ACTIVE | INPUT | 3 = 12 BIT OUT MODE<br>2 = PEN RECORD MODE (3X SPEED)<br>0 = PEN RECORD MODE (2X SPEED) |
| 2 | 1<br>2<br>4<br>8 | REMOTE I/O<br>NOT USED<br>NOT USED<br>NOT USED | 2 | EXECUTE I/O MODE | INPUT | 2ND DIGIT SIMULATES A PULSE INPUT FROM PDM 70 ON SECOND TURN AROUND (SEE TYPICAL PROGRAM)<br>1 - 0 = EXECUTE OUTPUT<br>0 - 0 = NO EXECUTE OUTPUT<br>[TO REINSTATE FROM I/O EXEC., READ ALL LOCATIONS] |
| 3 | 1<br>2<br>4 | HOLD LAST<br>LIVE<br>HOLD NEXT | 3 | STORE LAST SAMPLE<br>LIVE<br>STORE NEXT SAMPLE | INPUT | 1 - 0 = STORE LAST<br>2 - 0 = LIVE<br>4 - 0 = STORE NEXT |
| | | REMAINING AVAILABLE DIGITS NOT USED | | | | |

NOTE. OUT DONE STROBES DATA OUT/EA "EOT" INTO "J" MOD

TYPICAL PROGRAM
$$\left.\begin{matrix}3\\0\\2\end{matrix}\right\}\text{ FUNCTION CODE}$$
(EOT) FOLLOWED BY
$$\left.\begin{matrix}3\\0\\0\end{matrix}\right\}\text{ RESET CODE}$$
(EOT) & NOW READY FOR NEXT COMMAND

Fig. 16 — Input encoding — NI scope — CAMS

| 1st Character | (Pin 16) Bit 1 State | (Pin 15) Bit 2 State | Resultant Mode |
|---|---|---|---|
| 0 | Lo | Lo | Pen record at 1X speed |
| 2 | Lo | Hi | Pen record at 3X speed |
| 3 | Hi | Hi | 12-bit parallel digital output mode |

Pin 20 of the "E" module is used by the computer to remotely perform the manual function of depressing the "I/O Execute" button. This is accomplished with a negative-going pulse on Pin 20 as shown in Fig. 15. Once the scope has been placed in the 12-bit digital output mode, data are made available word by word under control of a clock input on the "E" module Pin 11 as shown. The clock pulse used here is the "out-done" pulse generated on the "E" module each time that the program within the PDM 70 sets up new commands on the output of the "E" module. The program for the PDM 70 is written such that the computer need send only an EOT to cause the PDM 70 "P" module to execute a new "E" module output and hence a new strobe into the digital scope for output of the next clocked word.

The state that the digital scope is placed in is controlled by the state of data bits on PDM 70 "E" module Pins Y, Z, and 22 as shown.

The 12-bit data words are brought back to the PDM 70 and converted into four BCD characters plus a fifth character for sign and a sixth character for mode status as shown on Fig. 17.

**X-Y Recorder (Hewlett Packard No. 7046A)**

General Specifications of Interest:

Two-pen recorder
Input sensitivity per pen: 0.2 V/cm (0.5 V/in.) to 4 V/cm (10 V/in.)
Time base: Six speeds from 0.2 s/cm (0.5 s/in) to 40 s/cm (100 s/in)
Accuracy: ±0.2% of full scale
Linearity: ±0.1% of full scale

The X-Y recorder is used in the system to provide response curves from the system operating in the manual mode. The X drive is provided from the frequency synthesizer dc output (0-10 V). The synthesizer scales any selected sweep frequency range into a 0-10 V dc level for such recording purpose. The Y drive comes from either or both of the SDVM dc outputs. The SDVM develops a dc voltage proportional to the true rms amplitude of a gated ac signal being measured. This arrangement permits the recording of response data directly as a backup mode without addressing the computer at all. The unit is integrated into the system through the patch panel as shown on Fig. 2.

## NI SCOPE
## ( D-MODULE INTERFACE )

| PDM 70 INPUT DIGITS | WT. | SCOPE INTERFACE BITS | DIGIT MAKE-UP | PDM 70 OUTPUT DECODE |
|---|---|---|---|---|
| 1 (MSD) | 1<br>2<br>4<br>8 | DATA BIT ($2^9$)<br>" " ($2^{10}$)<br>NOT USED<br>NOT USED | 1 (MSD) | 1st OCTAL DIGIT OF VOLTAGE MEAS |
| 2 | 1<br>2<br>4<br>8 | DATA BIT ($2^6$)<br>" " ($2^7$)<br>" " ($2^8$)<br>NOT USED | 2 | 2nd OCTAL DIGIT OF VOLTAGE MEAS |
| 3 | 1<br>2<br>4<br>8 | DATA BIT ($2^3$)<br>" " ($2^4$)<br>" " ($2^5$)<br>NOT USED | 3 | 3rd OCTAL DIGIT OF VOLTAGE MEAS |
| 4 | 1<br>2<br>4<br>8 | DATA BIT ($2^0$)<br>" " ($2^1$)<br>" " ($2^2$)<br>NOT USED | 4 | 4th OCTAL DIGIT OF VOLTAGE MEAS |
| 5 | 1<br>2<br>4<br>8 | DATA BIT ($2^{11}$)<br>NOT USED<br>NOT USED<br>NOT USED | 5 | SIGN OF VOLTAGE MEAS. (0 = +, 1 = −) |
| 6 | 1<br>2<br>4<br>8 | DELIMITER<br>OUTPUT STATUS SIGNAL<br>NOT USED<br>NOT USED | 6 | DELIMITER & OUTPUT INTERVAL MEAS. (> = NOT IN OUTPUT MODE<br>< = YES IN OUTPUT MODE) |
| | REMAINING AVAILABLE DIGITS NOT USED | | | |

**REMARKS**

- READOUT AMPLITUDE IS IN OCTAL NUMBERS WHICH REPRESENT LEVELS AS SHOWN ON THE DISPLAY FORMAT BELOW.
- THE FIRST FOUR DIGITS IN THE TRANSMITTED OR DISPLAYED FORMAT ARE SIGNIFICANT AMPLITUDE NUMBERS
- THE FIFTH DIGIT IS USED TO IDENTIFY THE QUADRANT BEING READ
- THE SIXTH DIGIT SIMPLY INDICATES THAT THE NISCOPE IS IN THE OUTPUT MODE (TRANSMITTED NUMBERS ARE VALID ONLY WHEN THE NISCOPE IS IN THE OUTPUT MODE)

EXAMPLE:
A TYPICAL READOUT OF THE NI SCOPE IS INTERPRETED AS FOLLOWS

$\underbrace{1674}\ 0\ <$

POSITIVE VOLTAGE

OUTPUT MODE

OCT = 956 Dec = 956/2048 PORTION OF + SCREEN VALUE. NOTE THAT VALUE WILL CHANGE AS A FUNCTION OF THE RANGE SWITCH SETTING

| OCT | DEC | DISPLAY FORMAT |
|---|---|---|
| 3777 ↑ 0000 | 2048 ↑ 0 | (0) OR + QUADRANT |
| 3777 ↑ 0000 | 2048 ↑ 0 | (1) OR − QUADRANT |

Fig. 17 — Output decoding — NI scope — CAMS

**Large Screen Display (Tektronix No. 613)**

General Specifications of Interest:

Horizontal deflection: 1 V per 20 cm
Vertical deflection: 1 V per 15 cm
Beam origin position: Strapped to center-left
Display format: Strapped to rectangular
Z-axis turn on: $>$ +1 V, +20 V max
Z-axis turn off: $<$ +0.5 V
Z-axis impedance: 10 k$\Omega$, 50 pF
Stored resolution: 200 $\times$ 266 line pairs

The Tek-613 display is utilized in the system normally to provide a graphics display during the exercise of a program wherein the computer interactive dialog is displayed separately on the terminal display. In addition, the Tek-613 is used to display analog data for the system manual mode.

The display was designed for direct plug-compatibility with both the terminal (through the multiplexer card described in the terminal section of this report) and the hard copy unit.

A switching unit has been designed for this unit to provide either analog data input or digital data input according to the state of the terminal multiplexer card. For details of the switching circuit, refer to the terminal description in this report.

The display is integrated into the system as shown on Figs. 2 and 18.

**Hard Copy Unit (Tektronix No. 4610)**

General Specifications of Interest:

Input data: Digital and plug compatible with Tektronix 4010 terminal and/or Tek-613 display

Interface: Separate interconnect cable to terminal and Tek-613 display

Input selection: Push button selectable (separate NRL design)

The hard copy unit is designed by Tektronix to be utilized with their Tek-4010 terminal and/or their Tek-613 display. The option of multiple inputs was procured for this system application. Although the hard copy unit has the capability of remotely controlling one of several inputs to be copied, a simpler method was designed in-house for this application. Operationally it is necessary only to depress a hard copy select switch installed on the system console to select the hard copy source. The electronic diagram of the control system is shown on Fig. 19. The unit is integrated into the system as shown on Figs. 2 and 18.

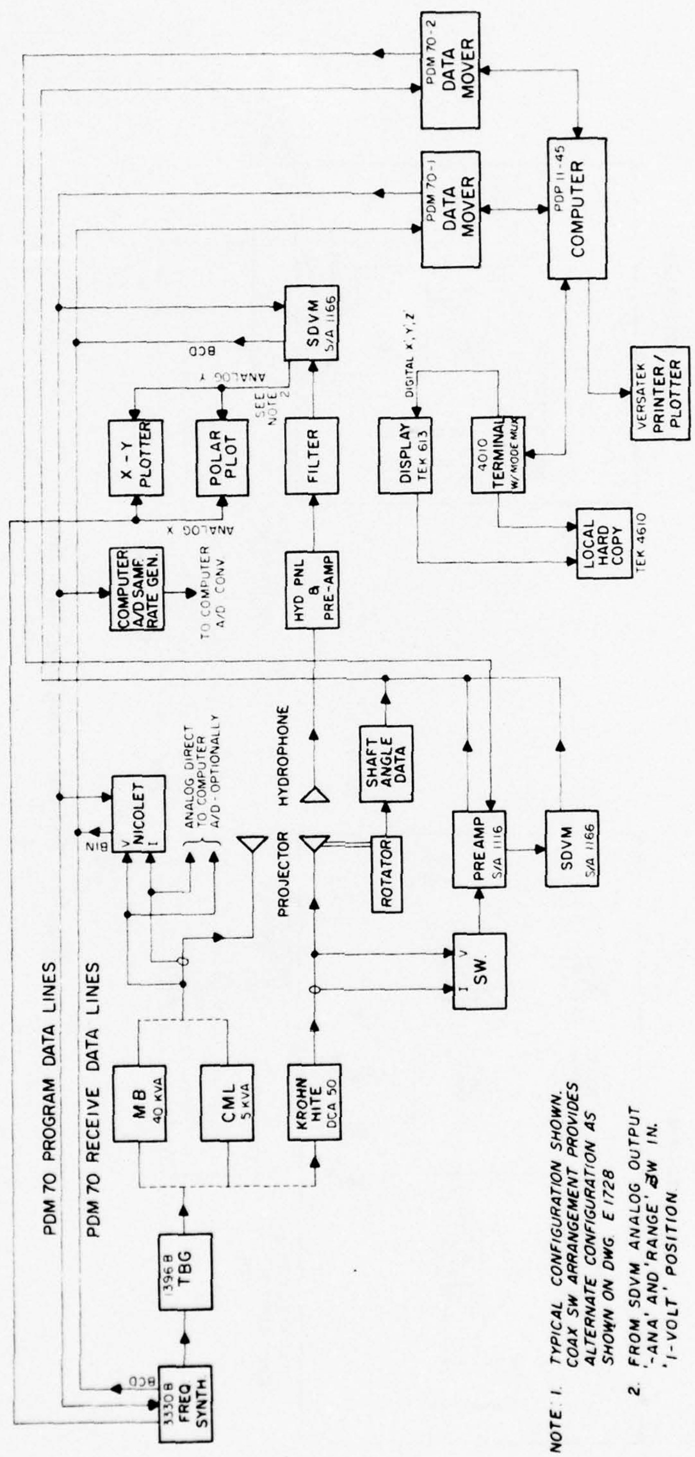



Fig. 18 — ATF control configuration CAMS

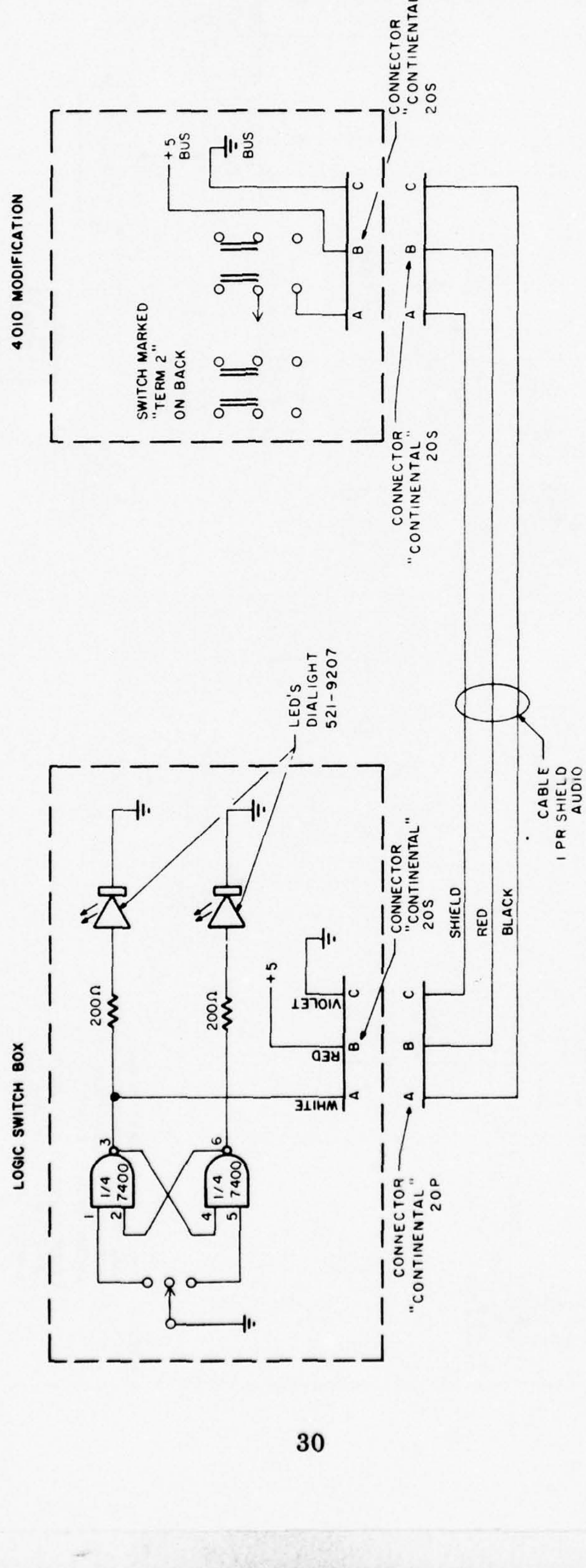



Fig. 19 — Terminal to hard copy switch unit

**Acoustic Coupler (RCA)**

General Specifications of Interest:

Communications rate: 110, 300 baud
Interface mode: Voltage or current loop
Input code format: Standard ASCII
Coupling method: Telephone handset, acoustical

**Modem (Bell Tel No. 103A with 8043 Aux.)**

General Specifications of Interest:

Communications rate: 110, 300 baud
Interface mode: Voltage or current loop
Input format: Standard ASCII
Communications modes: Full duplex, serial
Auxiliary arrangement: Auto origination, Auto answering, Alternate voice

Either the acoustic coupler or the modem may be utilized to communicate with an outside computer such as is available in time-sharing operations. Communication with an external computer is established *via* the system terminal. Once the external computer is placed in the text mode, communication is switched to the PDM 70 for direct transmission of measurement data. Remote control of the instrumentation is not intended; however, remote computation from transmitted data with return terminal plotting is an alternate backup mode in the event of any local computer catastrophic failure. In addition, the ability to communicate with outside systems permits real time or off-line data to be transmitted to any customer with appropriate receiving equipment.

A shortcoming of this mode of operation is the limitation of the modem and acoustic coupler to communicate at a 300-baud rate maximum. Future consideration of 1200- and 2400-baud links is planned.

**Communications Terminal (Tektronix No. 4010)**

General Specifications of Interest:

Communications code: Standard ASCII format (1 start bit, 7 data bits, plus 1 unused parity bit and 1 stop bit)

Interface mode: Voltage loop

Communications mode: Variable (2400-baud used herein)

Operating modes: Alpha (terminal writing alphanumerics) , Graph (vector drawing), Gin (interactive communications), Hard copy (output displayed data), Multiplex (switch to alternate display)

The terminal is integrated into the system as shown on Fig. 6. Functionally, basic communications are established between the measuring system and the remote computer by means of the terminal.

Typically, a computer stored program will be called on-line through the terminal. Interactive dialog will follow until the test parameters, etc., data are complete. The terminal then transmits the program run code to the computer, whereupon the computer takes command and runs the measurement. During a program's run, a curve of results may be called for in the program. In this case the computer may send a multiplex message to the terminal which will automatically switch the large screen Tek-613 display into the system and plot the data results of a curve thereon. A hard copy unit is interfaced to both the Tek-613 display and the Tek-4010 terminal for reproduction of either screen data as desired. It may be seen from the above example that all modes of operation of the Tek-4010 terminal are integral to the operation of the system.

The multiplexing mode is an option to the terminal hardware through Tektronix. The option consists of a multiplexer card inserted into the terminal minibus. The terminal interconnection for incorporating this option is shown in Fig. 20.

The multiplexer is energized by receipt of a specific command received either from the terminal keyboard or from the computer. The multiplexer responses to received input commands are as follows:

| Terminal/Computer Input Command | Multiplexer Interpretation |
|---|---|
| Control (↑) Shift K01 | (↑ Shift K) multiplexer attention, the following two characters are to be interpreted as multiplex instruction. (Ø) Multiplexer card in terminal minibus slot location Ø, follow instructions of the next command character.<br>(1) All subsequent data from either the terminal or computer are to be displayed on the terminal display only. |
| ↑ Shift K02 | Same as above except:<br>(2) All subsequent data from either the terminal or computer are to be multiplexed for display on the Tek-613 display only. |
| ↑ Shift K03 | (3) All subsequent data from either the terminal or computer are to be multiplexed for display on both the terminal display and the Tek-613 display. |

The hard copy unit is directly plug-compatible with the terminal. A hard copy of the data on the terminal display may be obtained by depressing the "make copy" button on the terminal keyboard. The terminal is integrated into the system as shown on Figs. 2 and 18.

**Synthesizer/Pulse Generator (Subsystem for A/D Trigger)**

General Specifications of Interest:

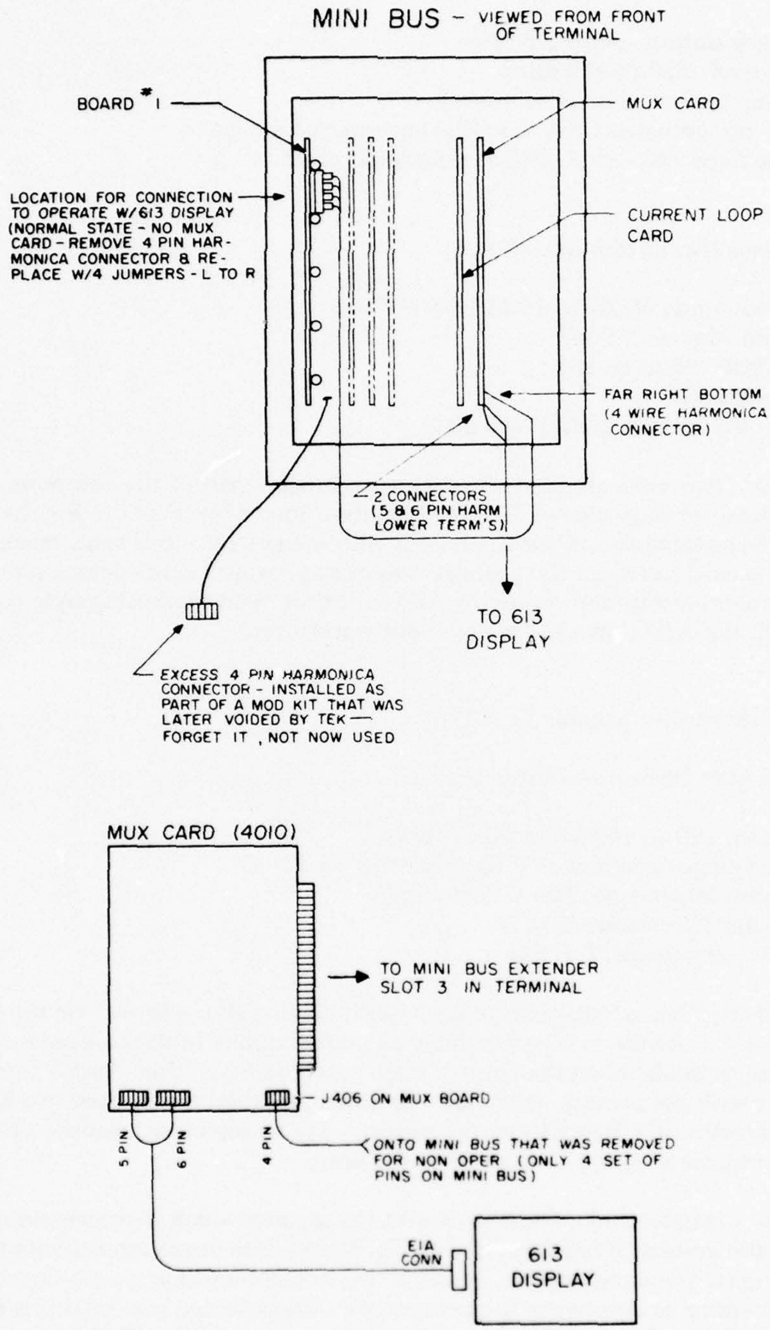



Fig. 20 — Terminal modifications to multiplex 613 display CAMS SA 1

*Synthesizer (Monsanto No. 3200A)*

Frequency output: dc to 1.3 MHz
Output level: +20 to -70 dBm
Operating modes: Manual or remote
Remote programming: 8-4-2-1 BCD encoding of 9 digits
External Standard out: 1-MHz synchronous clock

*Pulse Generator (Data Pulse No. 100A)*

Triggered input: 50 Hz to 10 MHz @ 1 V rms
Input impedance: 2.5 kΩ
Pulse width: 35 ns to 10 s
Jitter: <0.15%
Output: 0.5 to 10-V pulses into 50 Ω

The above two units are used together as an integral part of the computer analog measurement system (see High-Power E, I, $\phi$ Measuring Subsystem Section, Fig. 34). The synthesizer is used to generate a sine wave coherent with the system signal synthesizer. The synthesizer output is used to trigger the pulse generator to provide a short duration pulse ($\simeq 1\ \mu s$) which, in turn, is used by the computer A/D converter as an external sample command, coherent with the A/D converter analog input waveforms.

**Preamplifier (Scientific Atlanta No. 1116)**

General Specifications of Interest:

Gain: -20 to +60 dB in 10-dB steps
Frequency response: 10 Hz to 2 MHz ±1 dB
Input impedance: 100 MΩ @ 50 pF
Output impedance: 75 Ω
Output voltage: 1 V rms

This preamplifier is hardwired in series with "Hydrophone Input" on the "Hydrophone Panel." It may be operated either manually or under control of the computer. The output of this preamp is available on the console main patch panel as "Rec Amp." There is an integral filter with the preamp which may be either switched out or used in a high-pass, low-pass, or bandpass mode. In addition, the preamp may be used in a balanced or single-ended mode; however, the single-ended mode is used here.

There is a remote control unit used with the preamp which is connected to the PDM 70 as shown in the integration of Figs. 21 and 22. The remote operation is limited to selection of gain setting *via* the computer. In addition, the control unit has a push-button arrangement for increasing or decreasing the preamp gain. The selected gain setting is illuminated on the control panel. The unit has been modified to also send the PDM 70 a control signal corresponding to the particular gain setting selected. This is also shown on Figs. 21 and 22. Input encode and output decode data for communication between the preamp and the PDM 70 are shown on Figs. 23 and 24.

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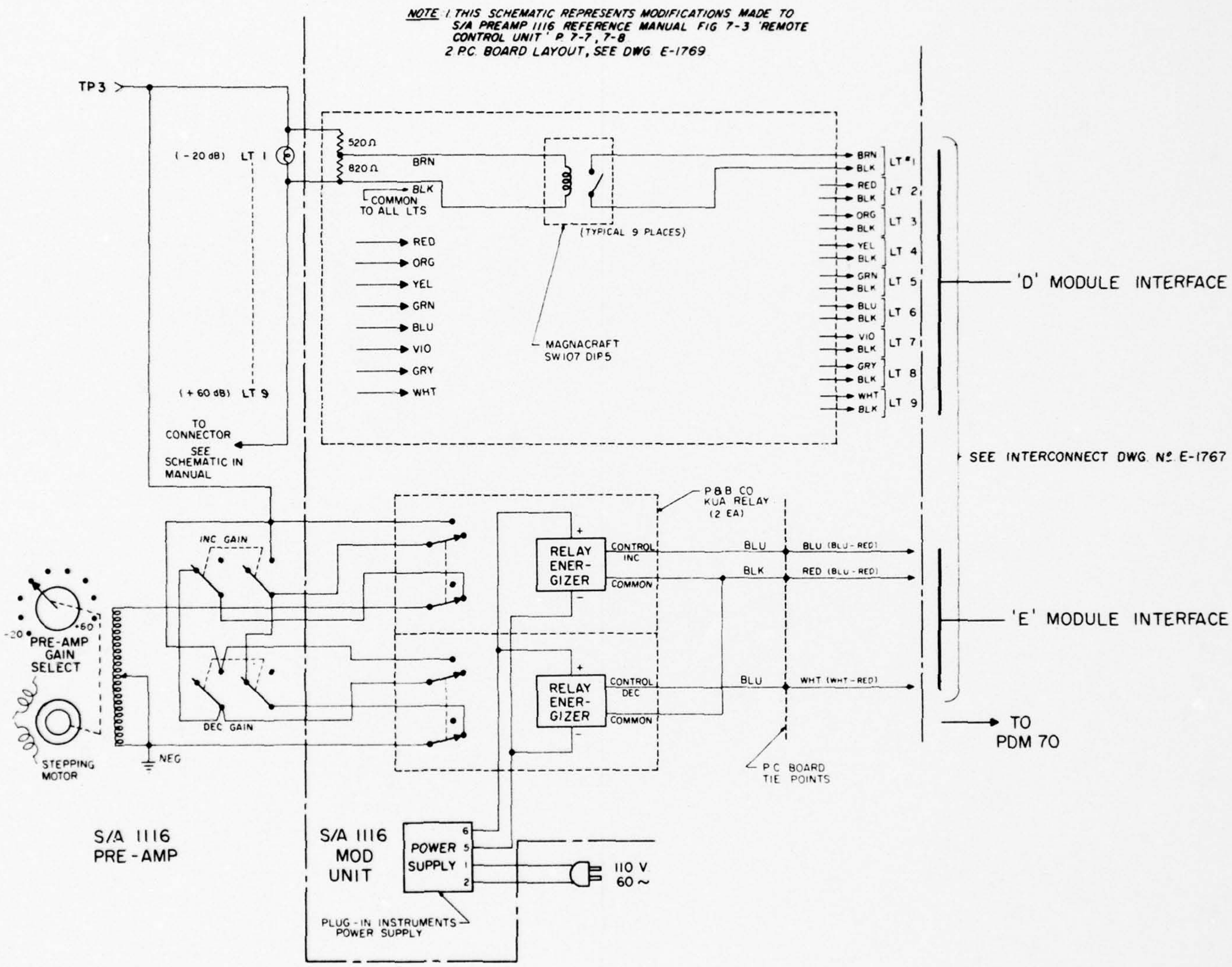


Fig. 21 — S/A 1116 preamp modification drawing CAMS

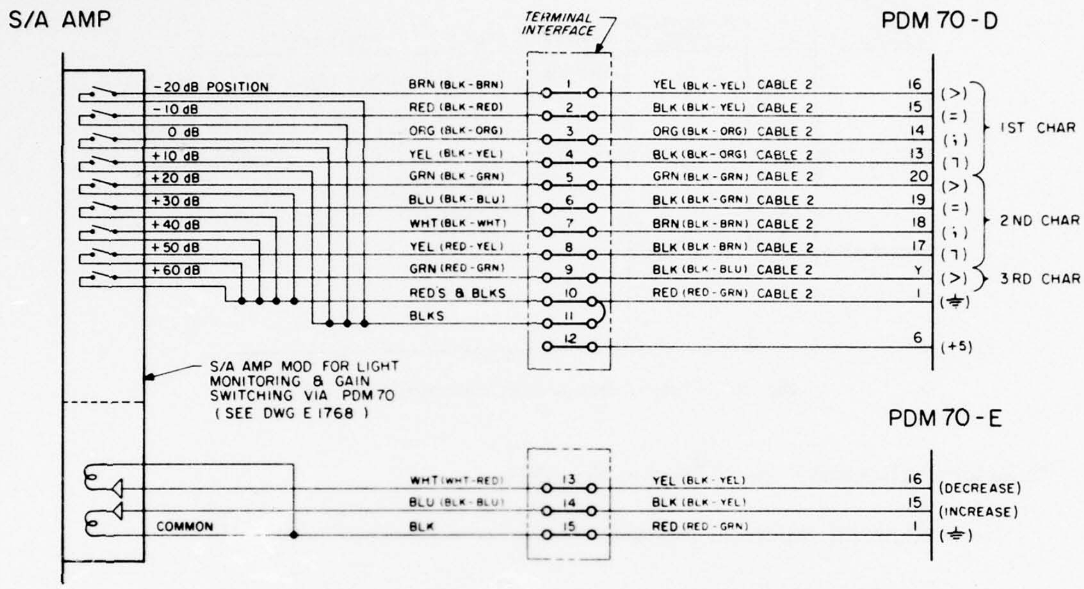


Fig. 22 — S/A preamp/PDM 70 interconnection diagram CAMS

S/A PRE-AMP
"E" MODULE
ADDRESS <

| COMMAND DESIGNATION | BIT WT | DIGIT NOMENCLATURE | REMARKS |
|---|---|---|---|
| 1 | 1 | DECREASE AMP GAIN 10 dB | SEE NOTE 1 |
| 2 | 2 | INCREASE AMP GAIN 10 dB | SEE NOTE 1 |

NOTE 1. A COMMAND TO (1) INCREASE OR (2) TO DECREASE MUST BE FOLLOWED BY AN 'EOT' & A (0) COMMAND 'EOT' TO COMPLETE EACH COMMAND SEQUENCE

Fig. 23 — Input encode — S/A preamp CAMS

S/A PRE-AMP
"D" MODULE
ADDRESS =

| DISPLAYED DIGIT SEQUENCE | BIT WT | DISPLAYED SYMBOL | DIGIT NOMENCLATURE | REMARKS |
|---|---|---|---|---|
| 1 | 1 | > | AMP GAIN = −20 dB | MODES (0) & (2) ONLY AVAILABLE IF MODE '0' IS COMMANDED FROM PDM 70, THE DISPLAYED DIGIT SEQUENCE SHOWN HERE WILL BE PREFACED BY TWO ADDITIONAL CHARACTERS TO IDENTIFY CARD ADDRESS & SELECTED MODE CHARACTERS NOT ACTIVATED ARE TRANSMITTED AS (?) |
| | 2 | = | −10 dB | |
| | 4 | ; | 0 dB | |
| | 8 | ⌝ | +10 dB | |
| 2 | 1 | > | +20 dB | |
| | 2 | = | +30 dB | |
| | 4 | ; | +40 dB | |
| | 8 | ⌝ | +50 dB | |
| 3 | 1 | > | +60 dB | |

Fig. 24 — Output decode — S/A preamp/PDM 70 CAMS

### Phase Meter (General Purpose Wiltron No. 351)

General Specifications of Interest:

Resolution of 0.1°
Offset 180°
Input down to 1 mV without preamps
Meter scale readout
CW operation
Frequency range 10 Hz to 2 MHz
6 meter ranges from 5° to 180°

This instrument is mounted in the control console as a general-purpose type of test equipment. Frequently, it is desirable to test portions of the operating system itself relative to phase performance. This instrument becomes quite handy because it is easy to use and gives a quick, direct measurement of phase. It is, however, limited to situations where tests may be conducted in a CW mode.

### Scopes (Hewlett Packard No. 1217B and Tektronix No. 7603)

The types of scopes, currently traded in and out of the system, are used for general-purpose testing as well as their normal mode as monitors of input waveforms being measured simultaneously on separate SDVMs.

### Polar Plotter System

General Specifications of Interest:

*Positioner (S/A No. 5105B)*

400° rotation and stop
Antibacklash on gear train
Vertical load: 907 kg (2000 lb)
Drive motor: 1/15 hp
Delivered torque: 54.2 N-m (40 ft-lb)
Max operating speed: 3 rpm
Readout position accuracy: 0.05°

*Display (S/A No. 1842)*

Two-channel digital display
Accuracy: 0.01°
Resolution: 0.01°
Update rate: 100 Hz/s
Variable offset: 360°
Digital output: 8-4-2-1 BCD

*Recorder (S/A No. 1536A)*

Max table speed: 10 rpm
Chart position error: $<0.25°$
Pen response accuracy: ±0.15 dB (log)

*Control Unit (S/A No. 4111)*

0-120 V continuously variable

*Pen Function Amplifier (S/A No. 1555-6)*

Direct-current input (AUX POSITION): 0 to + 1 V dc
Scale expansion: X1, X2, X3, X4

The entire polar plotter system is interconnected with the above components as shown in Fig. 25. The control unit mounted in the control console sends a rotational drive signal to the positioner located on top of the anechoic tank hatch. The rotator turns the shaft extending into the pressurized tank thereby changing the orientation of the integrally attached specimen at the end of the shaft.

A servo signal is sent back from the rotator to the recorder and digital display to record the proper angle position of the rotator. Power for the Pen Function Amplifier (PFA) as well as reference phase signals (when used) is provided from the power supply and servo amp unit.

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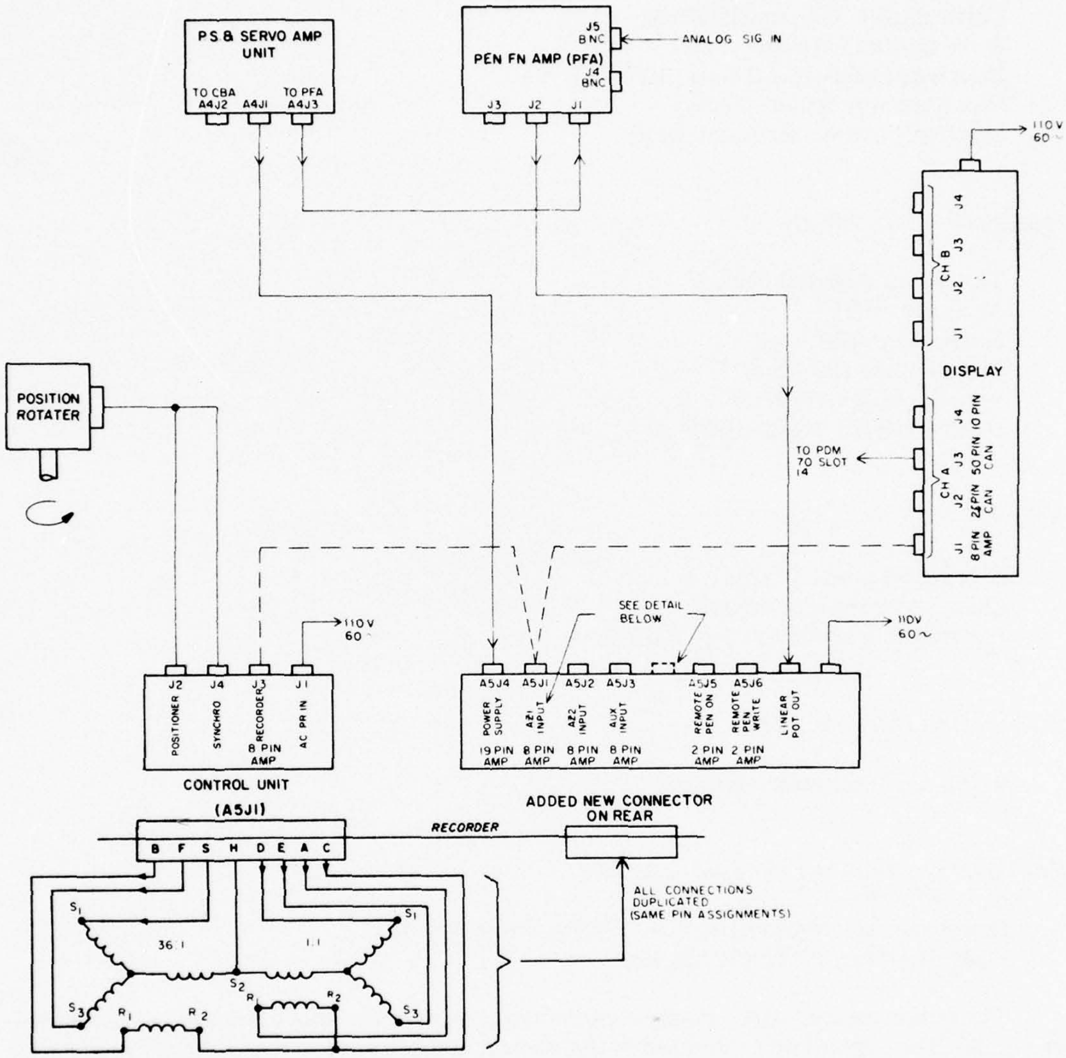



NOTES 1 CONTROL UNIT J3 SAME AS J4 EXCEPT FOR A,B,C PINS CARRYING SYNCHRO SIGNALS. ALL USRD PROVIDED CABLE REQUIRED.

2 ALL 110V-60~ POWER TO GO TO SAME PHASE.

3 —— CUSTOMER CABLE
- - - USRD CABLE

**Fig. 25 — Intercable diagram for S/A positioner, ATF CAMS**

An acoustical signal is received from a hydrophone in the anechoic tank and measured in amplitude by a true rms detector in the system SDVM. A 0-1 dc voltage proportional to the ac amplitude of the receive signal is available at the "analog out" port of the SDVM and "SDVM ANA" on the patch panel. This signal is patched to the PFA as the "analog signal in" shown in Fig. 25. The PFA adjusts the gain and conditions the signal to drive the pen in the recorder. Accordingly, a pen deflection in proportion to received signal level at a defined angular position is recorded on the polar plotter, continuing as long as the rotator is driven.

**Filter (Rockland System No. 816)**

General Specifications of Interest:

16 independent channel capacity
48 dB/octave
Butterworth design (Bessel also available)
Hi-pass, lo-pass, or bandpass — card selectable
All channels are programmable
Frequency range 0.01 Hz to 150 kHz

The filter is intended to be an integral part of the receive system when measurements are made at a frequency range below 150 kHz. It is integrated into the system in such a way that it may be placed under control of the computer. It is one of two selectable filters in the receive system; however, the first one is an integral part of the S/A 1116 preamp which is always in the receive circuit and has a variable frequency range to 500 kHz. The programmable Rockland filter has its input and output available at the system main patch panel as shown in Fig. 26. The encoding requirements for remote operation are defined in Fig. 27. The interconnection diagrams are shown in Figs. 28 and 29.

**Power Conditioner (Pacific Electronics No. 110H)**

General Specifications of Interest:

Operating line voltage (normal): 105-125 V rms
Operating line frequency: 47-500 Hz
Output frequency selectable at: 47-500 Hz
Frequency accuracy: 0.5%
Frequency stability: 0.02% (10 h)
Amplitude stability: 0.5% (10 h)
Output voltage: 0-125 V rms
Output current: 0-8 A

The power conditioner has been designed into the system to provide a clean power source for driving the digital equipment. The two PDM 70's, the terminal, and the Tek-613 display are all operated from this power source.

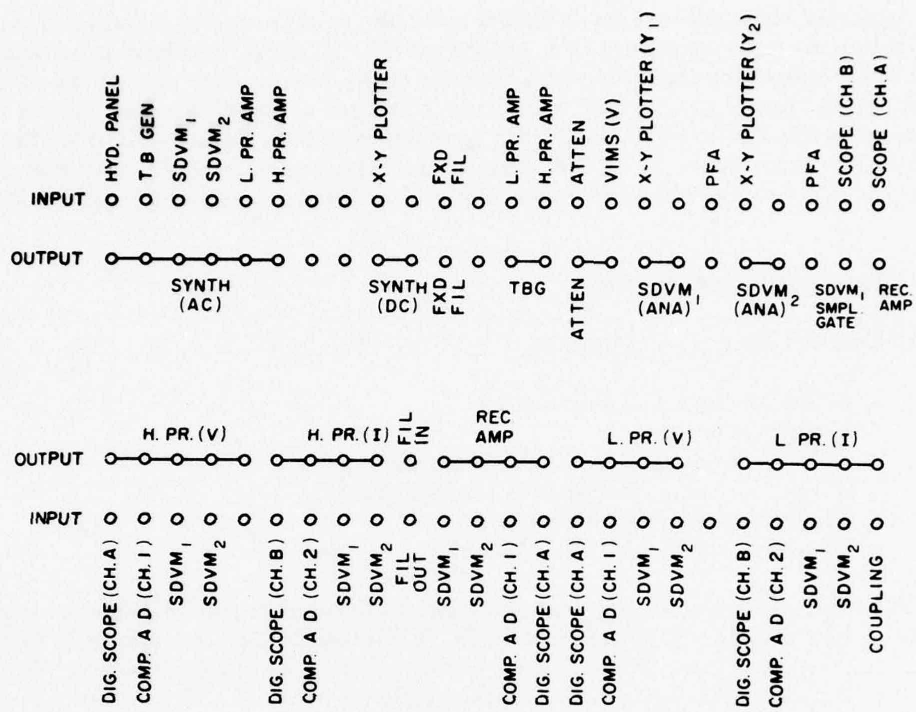



Fig. 26 — Switching layout for CAMS

## Transmit and Hydrophone Panels

The transmit panel mounted in the console is designed to provide flexibility of selecting power amplifiers. Selection of a special F27 transducer in the output circuit and monitoring configurations of output current and voltage waveforms are available. The associated layout and subsystem interface drawings are Figs. 30, 31, and 32.

The hydrophone panel is designed to permit separate receive system calibration, receive hydrophone inputs with either standard cable connectors or bare wire inputs, and supply and preamp voltages that may be required and provide for coupling measurements. The layout and system integration drawings are shown in Figs. 30, 32, and 33.

## Power Amplifiers and Matching Transformers

General Specifications of Interest:

*Power Amplifier (Krohn Hite No. 7500)*

Power: 75 W
Frequency range dc: 1 MHz (useful to 2 MHz)
Voltage output: 140 V rms max.

| CHARACTER SEQUENCE | CHARACTER TRANSMITTED | CHARACTER MEANING | REMARKS |
|---|---|---|---|
| | > | SELECT '1' CHANNEL (H.P) | HI PASS |
| 1 | = | SELECT '2' CHANNEL (L.P) | LO PASS |
| | > | SELECT C.O. FREQ 1 HZ | |
| | = | 2 | |
| | < | 3 | |
| | ; | 4 | |
| | : | 5 | |
| | 9 | 6 | |
| | 8 | 7 | |
| | 7 | 8 | |
| | 6 | 9 | |
| | 5 | 10 | |
| | 4 | 11 | |
| | 3 | 12 | |
| | 2 | 13 | |
| 2 | 1 | 14 | |
| | > | 10 | |
| | = | 100 | MULTIPLIER |
| | < | 1000 | |
| 3 | ; | 10,000 | |
| | 1 | PRESET | SEE FILTER |
| | 2 | LOAD COMMAND | MANUAL FOR |
| | | | DESIRED |
| 4 | | | COMBINATION |

NOTE: EACH 'PRESET' OR 'LOAD' COMMAND MUST BE FOLLOWED BY AN 'EOT.'

Fig. 27 — Filter encoding from PDM 70 — CAMS

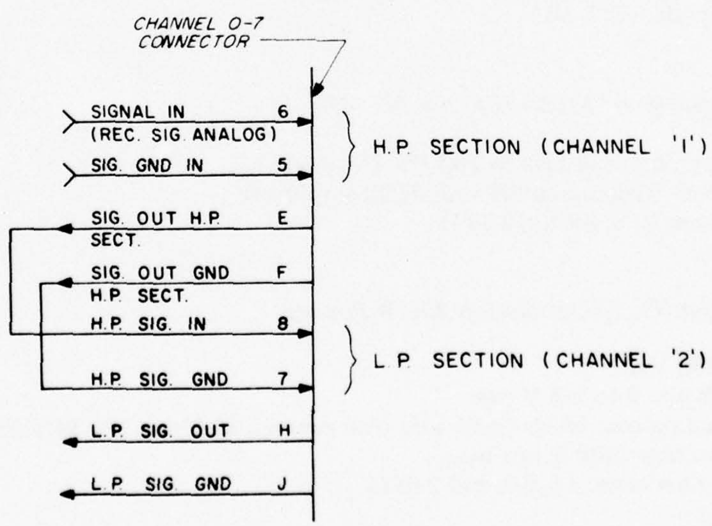



Fig. 28 — Programmable filter external connection thru channel 0-7 connector CAMS

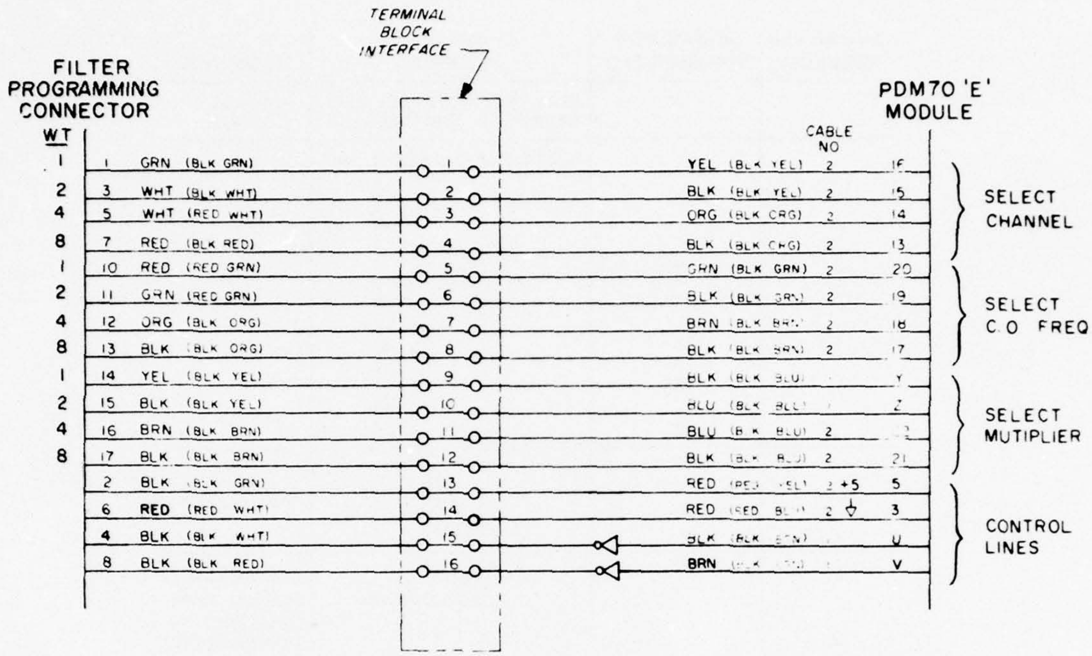



Fig. 29 — Filter programming connector to PDM 70 interconnection CAMS

Voltage gain: 0 to 40 dB
DC offset: 0 to 200 V dc
Input voltage: $\pm 20$ $V_p$ (X100) or $\pm 200$ $V_p$ normal
Input impedance: 1 MΩ

*Matching Transformer (Krohn Hite No. MT56)*

Frequency ranges: 30 Hz to 10 kHz, 10 to 500 kHz
Power level: (recommended with 7500 amplifier)
Impedances: 2, 8, 32 and 128 Ω

*Power Amplifier No. 2 (Optimation 250-W Power)*

Power: 200 VA
Input voltage: 0 to 2.5 V rms
Frequency ranges: 45 Hz to 60 kHz (full power), 35 Hz to 140 kHz (half power)
Output voltage: 300 V rms max.
Output impedance: 15, 60, and 240 Ω

These power amplifiers and matching transformers are used in the low-power configuration of the system and will be used interchangeably as the power and frequency requirements of each task dictate. They are shown on the integration drawings in Figs. 30 and 31.

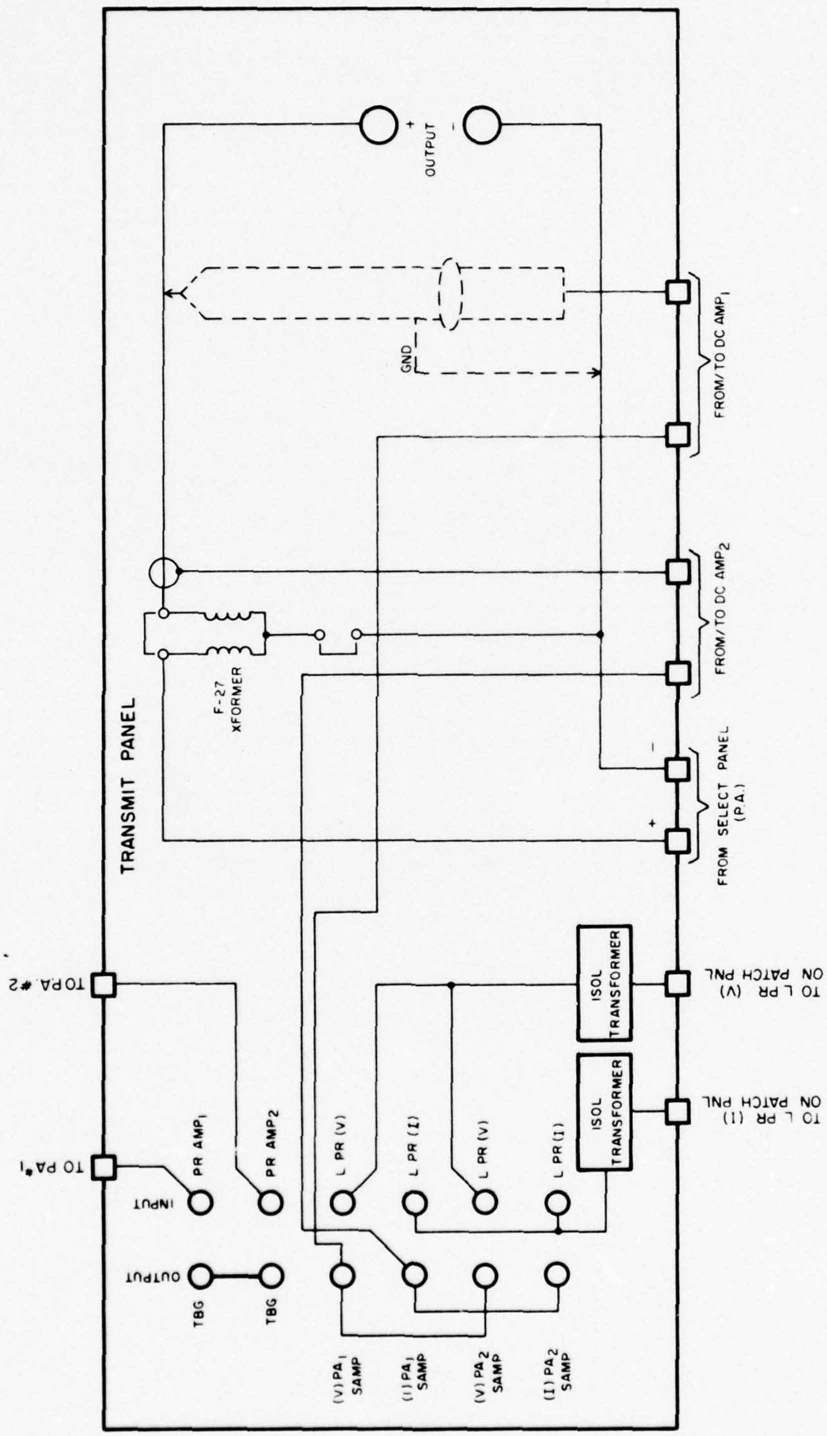



Fig. 30 — Transmit panel layout CAMS

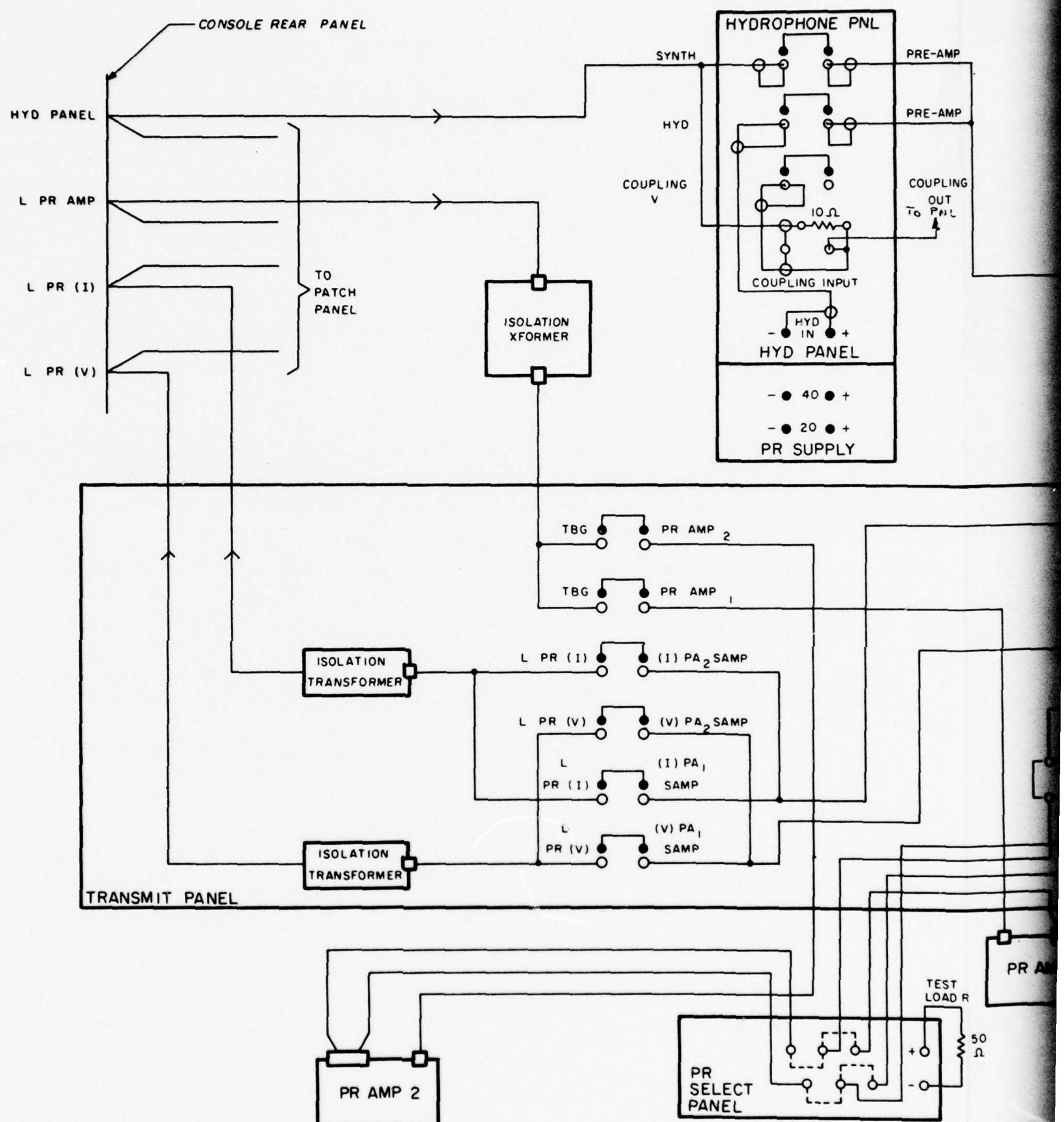



Fig. 31 — Transmit subsystem interface diagram CAMS

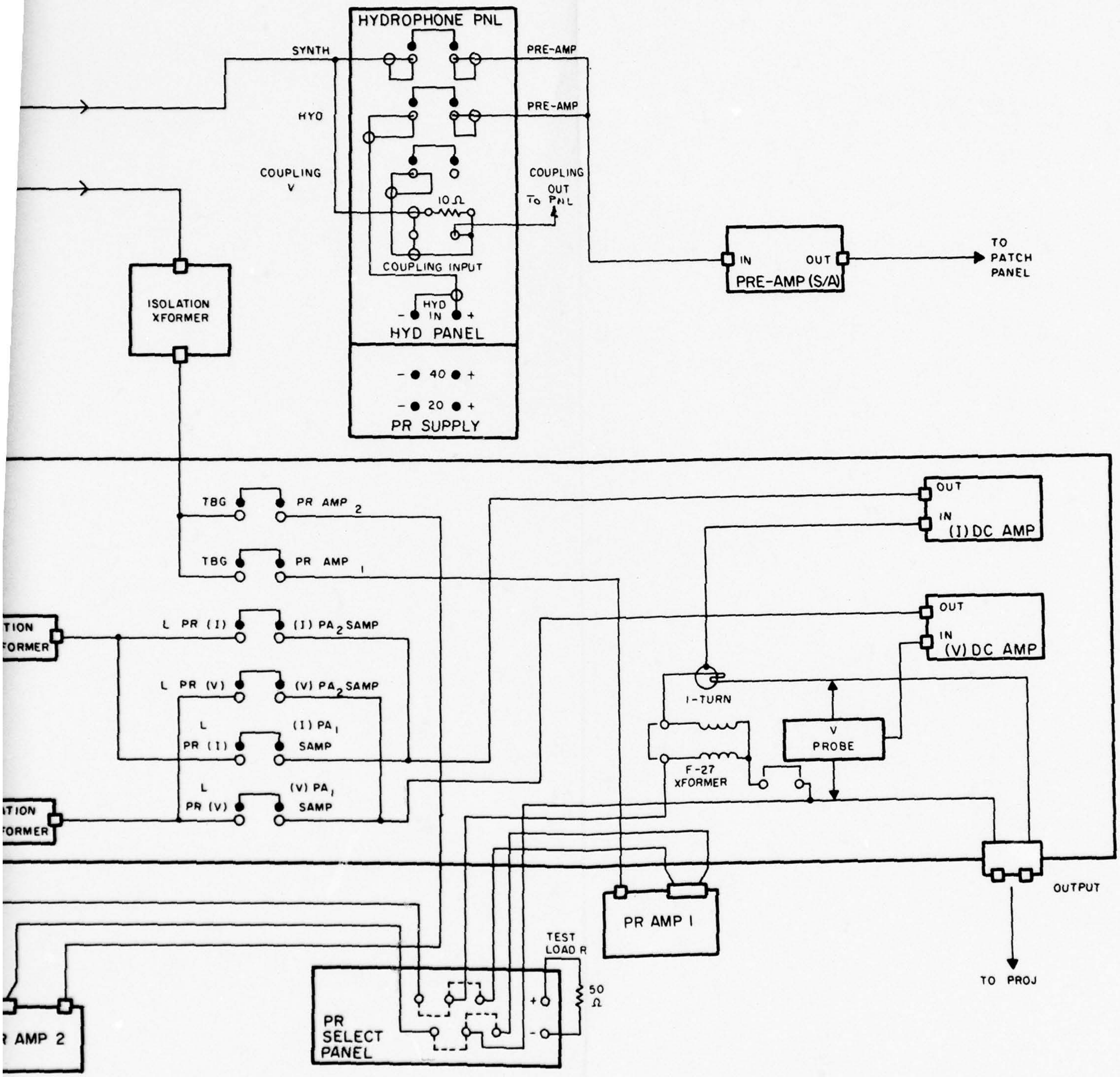



Fig. 31 — Transmit subsystem interface diagram CAMS

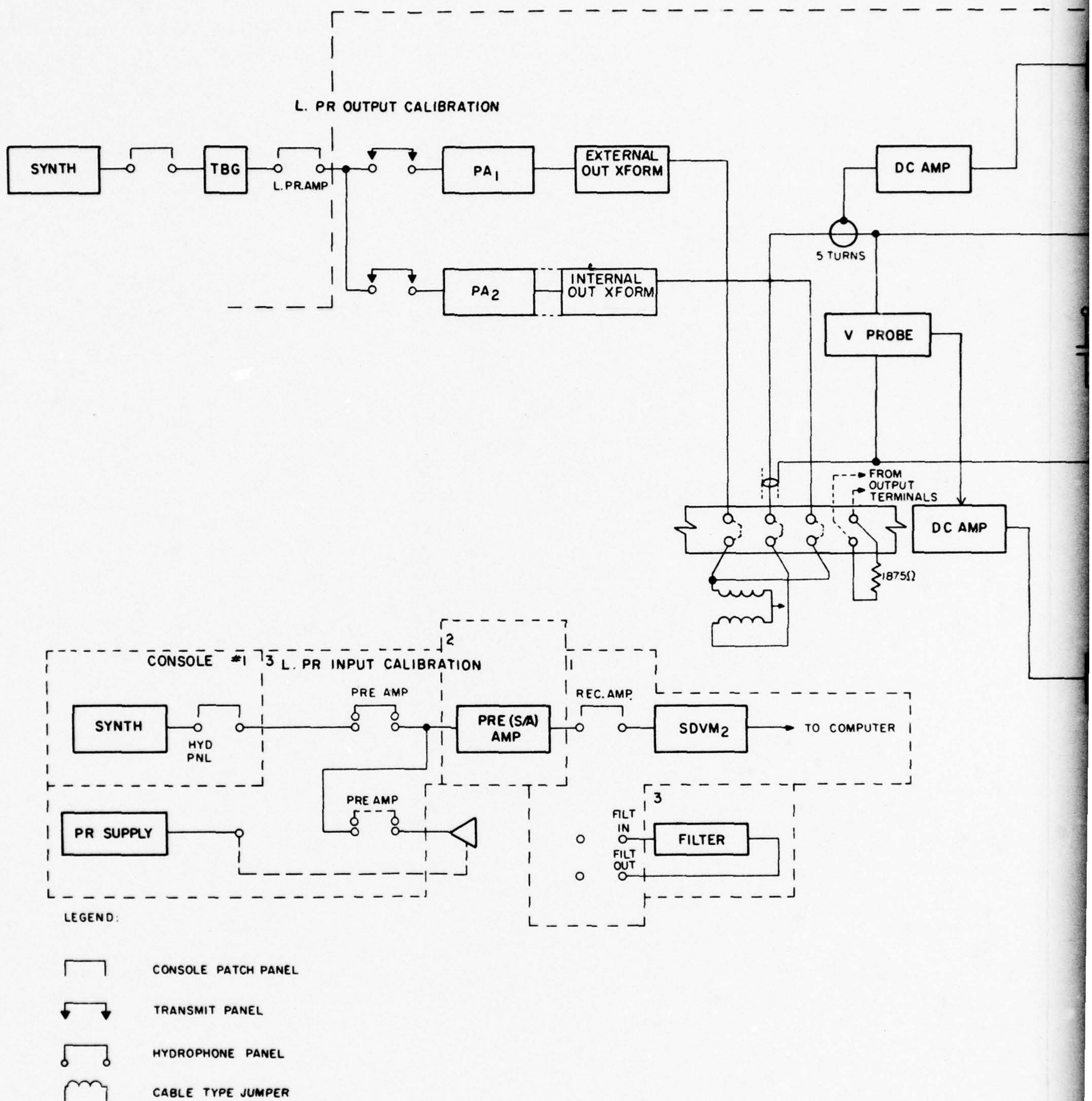



Fig. 32 — Transmit, receive, and calibration block diagram CAMS

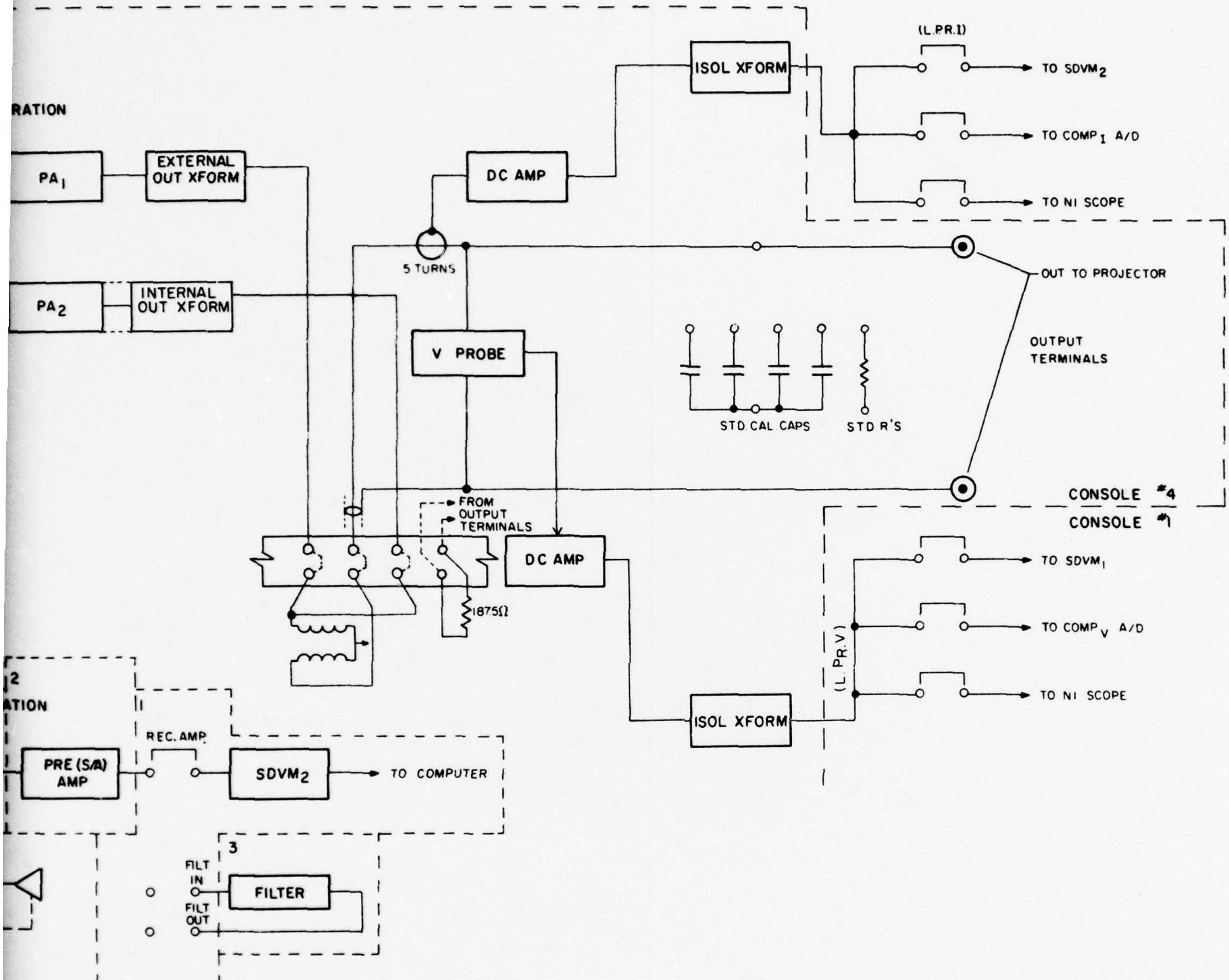



Fig. 32 — Transmit, receive, and calibration block diagram CAMS

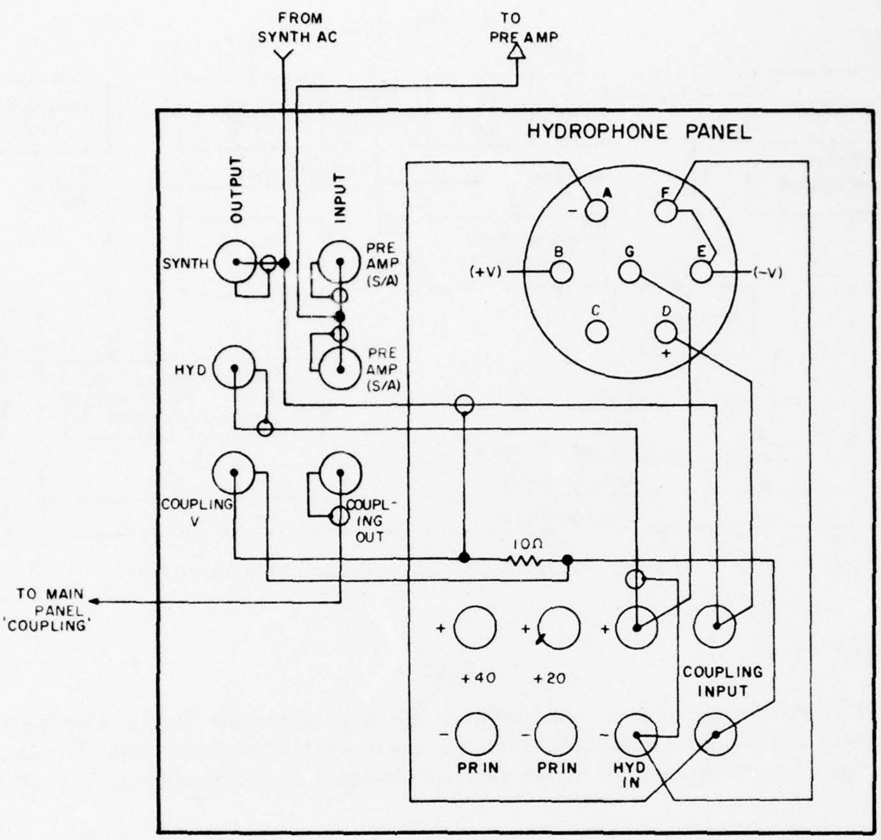



Fig. 33 — Hydrophone panel layout CAMS

## E&I Sample Amplifier (Dynamics No. 7525)

General Specifications of Interest:

Input type: Differential or single ended
Output type: Single ended
Gain range: 0 to 60 dB
Integral power supplies
Output voltage: 10 $V_{pp}$
Output impedance: 50 Ω
Bandwidth: dc -2 MHz

This amplifier is used in the low-power measurement configuration. One amplifier is used in each of the voltage and current sample lines to condition the sampled signals for measurement elsewhere in the system. These amplifiers are integrated into the system as shown in Fig. 31.

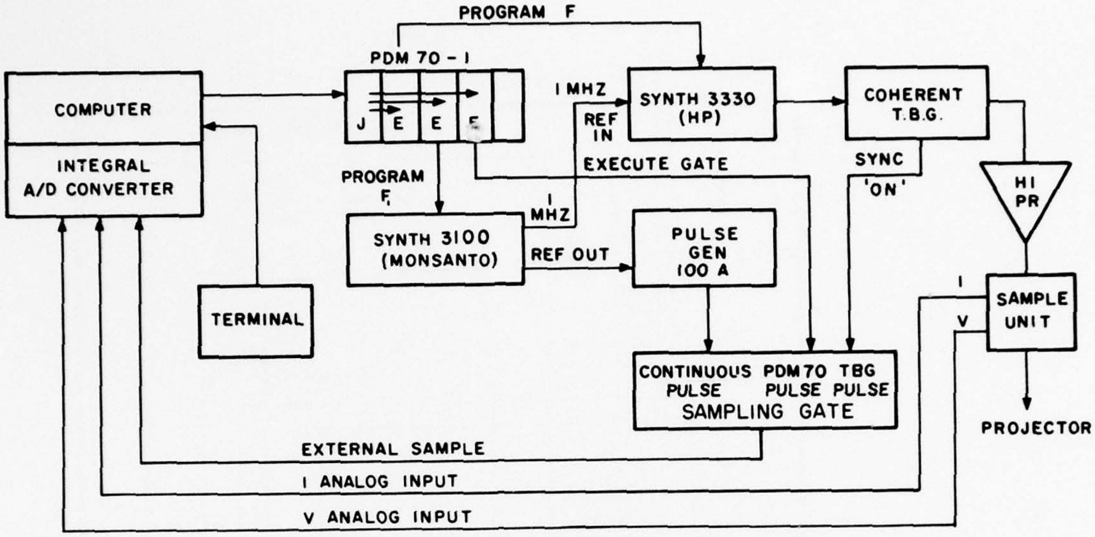



Fig. 34 — Block diagram of computer analog subsystem

## Carriage Control

The carriage control unit is mounted in the control console. It serves the purpose of moving the hydrophone relative to the projector inside the anechoic tank. This is accomplished by controlling a motor driven carriage mounted on tracks within the tank.

## SYSTEM INTEGRATION AND OPERATION

The computer-controlled measuring system will generate the necessary sound signal over a frequency range from 1 Hz to 1 MHz at 75 W, or 35 Hz to 140 kHz at 100 VA for low-power operation, or 1-60 kHz at 40 kVA for high-power operation. It will provide any required coherent bursting from one cycle of the driving frequency to 10 s and at similar repetition rates. The system will then measure any one of the desired driving parameters (voltage, current, or phase) with the computer on line. Simultaneously, the response voltage from a hydrophone may be measured as the system steps in frequency and resultant data may be presented to the operator from the computer as a plot, a listing, or any combination in real time. In addition, the system will provide pattern information to the operator in either polar or rectilinear format *via* the computer, simultaneous with the normal, local polar plot.

## HIGH-POWER E, I, $\phi$ MEASURING SUBSYSTEM

All signal interface with the computer is *via* serial digital form except for this special case where analog waveforms of voltage and current are connected directly to the computer A/D converter for processing. This subsystem has been particularly useful for the measurement of high-power immittance. A block diagram of the subsystem is shown in Fig. 34.

The function of this subsystem is to compute voltage, current, and phase of pulsed waveforms at high power (up to 40 kVA) under conditions of waveform distortion in either voltage or current. The desired accuracy of the resultant phase measurement is less than 0.5 degree.

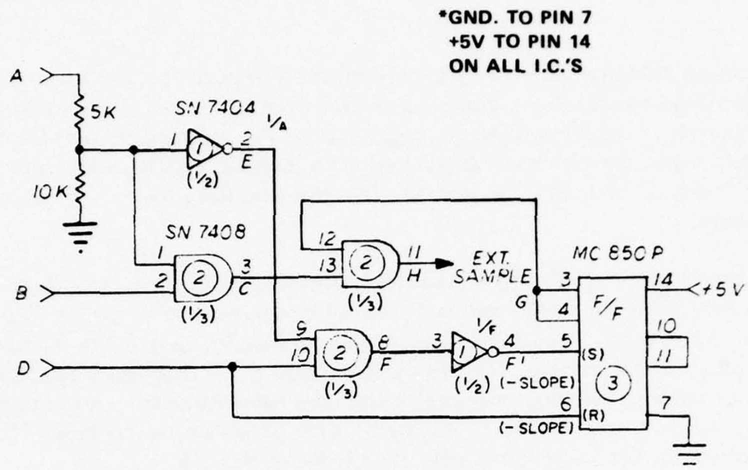
The analog data are currently sampled at the computer by the following special technique. Both synthesizers shown above have their 1-MHz clocks phase-locked together. Since the outputs of each synthesizer, regardless of the independently selectable frequency on each synthesizer, are coherent with their own integral 1-MHz clock, any number of samples per burst interval may be selected by choosing the proper ratio of synthesizer output frequencies.

This arrangement maintains the desired sampling technique, regardless of the signal-drive frequency. The only adjustment that may be required is to assure that the pulse generator width not exceed the period of one cycle of the Monsanto No. 3100 synthesizer frequency. Both synthesizers are programmable so that drive frequency and number of samples per burst interval may be programmed by the computer directly. The sampling trigger is sent to the A/D converter only when asked for by the computer *via* the PDM 70. The timing and schematic diagrams for this sample gate are shown in Fig. 35.

Operationally, the voltage, current, and phase of the projector-driving waveforms are measured in the following manner for the high-power subsystem. The HP 3330B synthesizer is set up to drive at the desired frequency range with an output amplitude of 1 V rms. The synthesizer ac output is patched to the toneburst generator input (see Fig. 26 ). The toneburst generator output is patched to the high-power amplifier. The high-power voltage sample is patched to the computer A/D channel one (1) or digital scope-channel A, and the high-power current sample is patched to the computer A/D channel two (2) or digital scope-channel B. The high-power amplifier used in the ATF is a 40-kVA amplifier manufactured by MB Electronics. The amplifier output transformer is terminated in a switching unit wherein E, I, and $\phi$ monitoring points are permanently arranged as shown in Fig. 36.

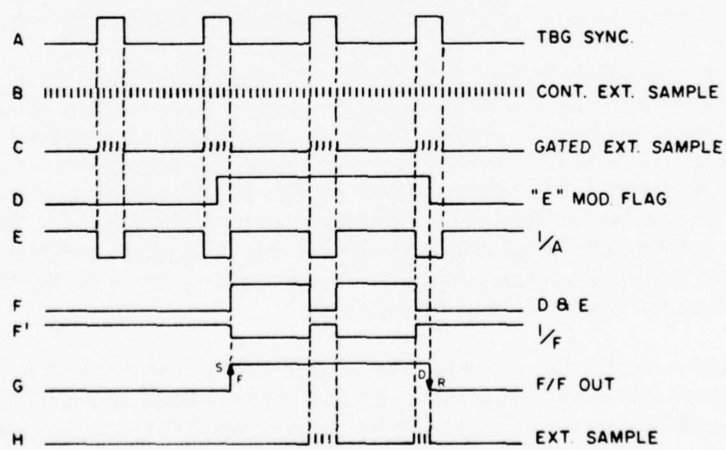
A sample of the drive voltage and current is picked off by the method shown above to preserve the E and I waveforms at the computer A/D converter, where the waveforms are digitized and analyzed to yield the relative phase. The biggest advantage of this type of instrumentation is that the phase relationship between E and I waveform fundamental components may be determined in the computer by Fourier analysis of the two waveforms regardless of the amount of distortion that may exist in either waveform. Many of the high-power transducers exhibit some nonlinear characteristics and have considerable distortion at high power. Hence, an accurate measure of relative phase is very difficult by other methods such as the older null-balance approach.

Alternately, the Nicolet scope may be used to digitize the sampled E and I waveforms and the resultant digital data sent to the computer *via* the PDM 70 route. Either the E or I signal may also be measured in amplitude by the console SDVM-to-computer link for transmit parameter *vs* response types of measurements.




SCHEMATIC DIAGRAM

NOTES:
1. CIRCUIT SOLVES PROBLEM W/TIME DATA A/D IGNORING TBG SYNC DURING THE EXT. SAMPLE MODE.
2. SIGNAL "D" ABOVE IS FROM PDM70-E MODULE, SLOT 5, ON 4TH CHARACTER, 1 WT. BIT. (NISCOPE, E MOD T.B., PIN 1 & BLK OF BLK-BRN PAIR FROM PDM 70)
3. CIRCUIT PROVIDES EXT. SAMPLE ONLY WHEN ASKED BY COMPUTER-PDM 70 & ASSURES THAT 1ST EXT. SAMPLE GROUP PROVIDED WILL BE A FULL TBG GATE WIDTH WIDE.
4. SEE DWG E1743 FOR BOARD LAYOUT.




TIMING DIAGRAM

Fig. 35 — Time data A/D — external sample modification CAMS

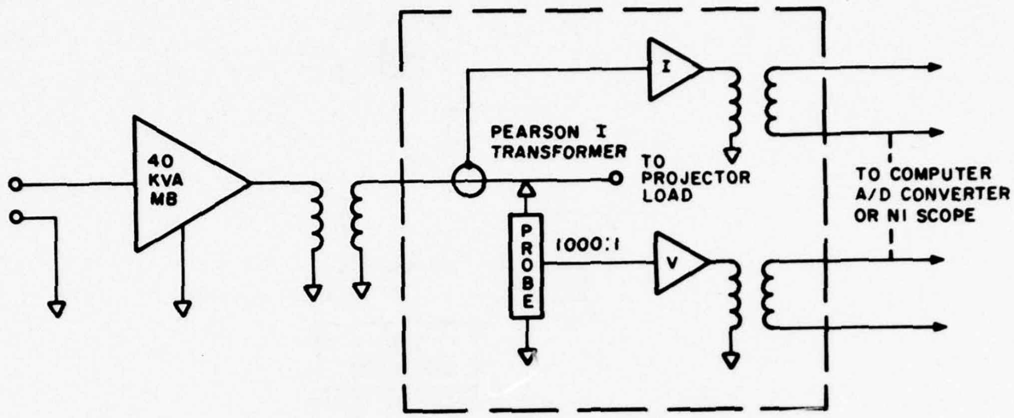



Fig. 36 — High power, E, I, and Ø monitor instrumentation

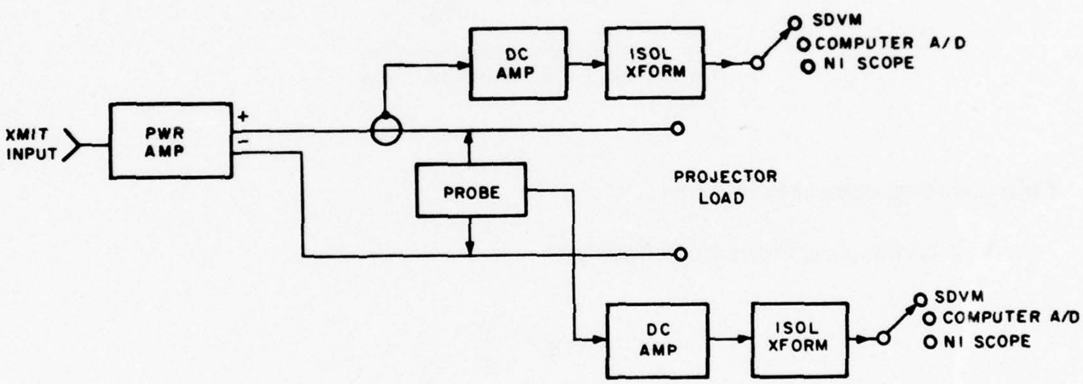



Fig. 37 — Low power, E, I, and Ø sampling circuit

## LOW-POWER E, I, Ø MEASURING SUBSYSTEM

Operationally, the low-power voltage, current, and relative phase are determined in a manner similar to that in the high-power mode. The transmit E, I, and Ø parameters are measured as shown in Fig. 37 (Also see Fig. 32 for details.).

The low-power voltage or current samples appear at the patch panel of the new system and may be patched either to the computer A/D converter or to the Nicolet scope for E, I, and Ø measurements. Just as in the case of the high-power measurements, either E or I may be patched to a SDVM for amplitude measurements in a transmit parameter *vs* response measurement mode.

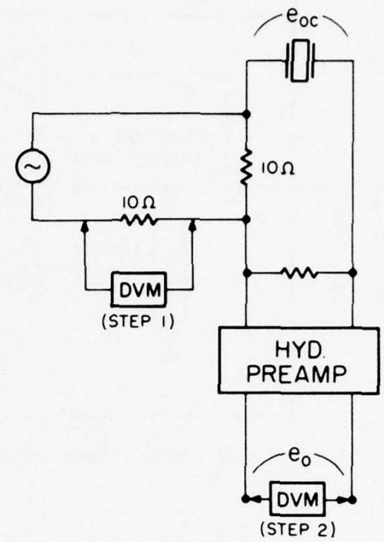



Fig. 38 — System interconnection for coupling measurement (old system)

**Coupling Measurement Subsystem**

Voltage coupling losses are defined as:

$$R_{\mathrm{VCL}} = \frac{e_{oc}}{e_o} \ ,$$

where $e_{oc}$ is the open-circuit voltage of the hydrophone equivalent generator and $e_o$ is the open-circuit voltage at the output of the hydrophone cables. (This includes preamps, cable losses, etc.)

Coupling loss measurements were made with the old system in a two-step procedure with the system arrangement shown in Fig. 38.

In this configuration, an ac voltage is applied to the I terminals shown in step 1 of Fig. 38. The ac voltage will be measured across the external 10-Ω resistor. The resulting voltage will be the same (neglecting measurement cable losses) as the voltage across the internal 10-Ω resistor. Since the 10-Ω resistor is small relative to the series Thévenin impedance of the crystal equivalent generator, the externally measured voltage also represents to a good approximation the crystal equivalent generator voltage.

The voltage coupling loss from the equation above may now be known if the output hydrophone cable voltage is measured. This is done as shown in step 2 of Fig. 38. Coupling measurements are made on the new system in an identical manner; however, the terminal layout for interconnection into this configuration is different, as shown in Fig. 2 and the

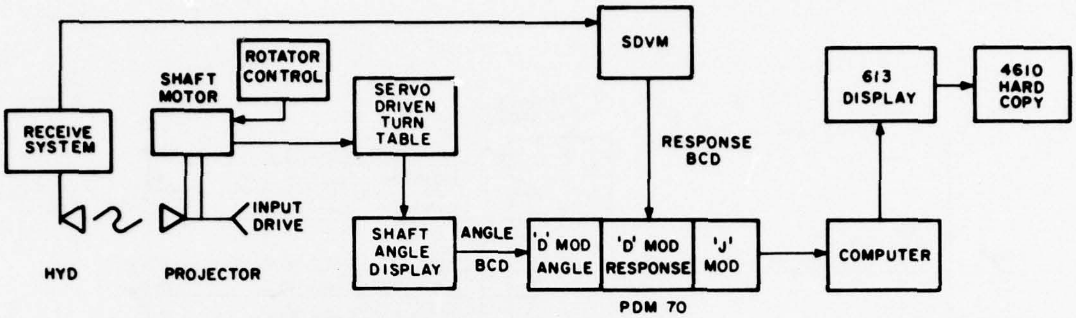



Fig. 39 — Pattern measuring hardware

| DIGIT SEQUENCE | #OF BITS | |
|---|---|---|
| 1 | 1 | SIGN OF DATA<br>0 = NEGATIVE, 1 = POSITIVE |
| 2 | 2 | MSD OF DATA<br>100's DIGIT |
| 3 | 4 | 10's DIGIT |
| 4 | 4 | 1's DIGIT |
| 5 | 4 | 1/10's DIGIT |
| 6 | 4 | 1/100's DIGIT |

EXAMPLE:

PDM 70 DISPLAY OF: 1 2 3 4 5 6
IS INTERPRETED AS: +2 3 4.5 6

NOTE: DECIMAL POINT ALWAYS PRECEEDS SECOND FROM LAST DIGIT AND IS THEREFORE NOT NECESSARY TO ENCODE.

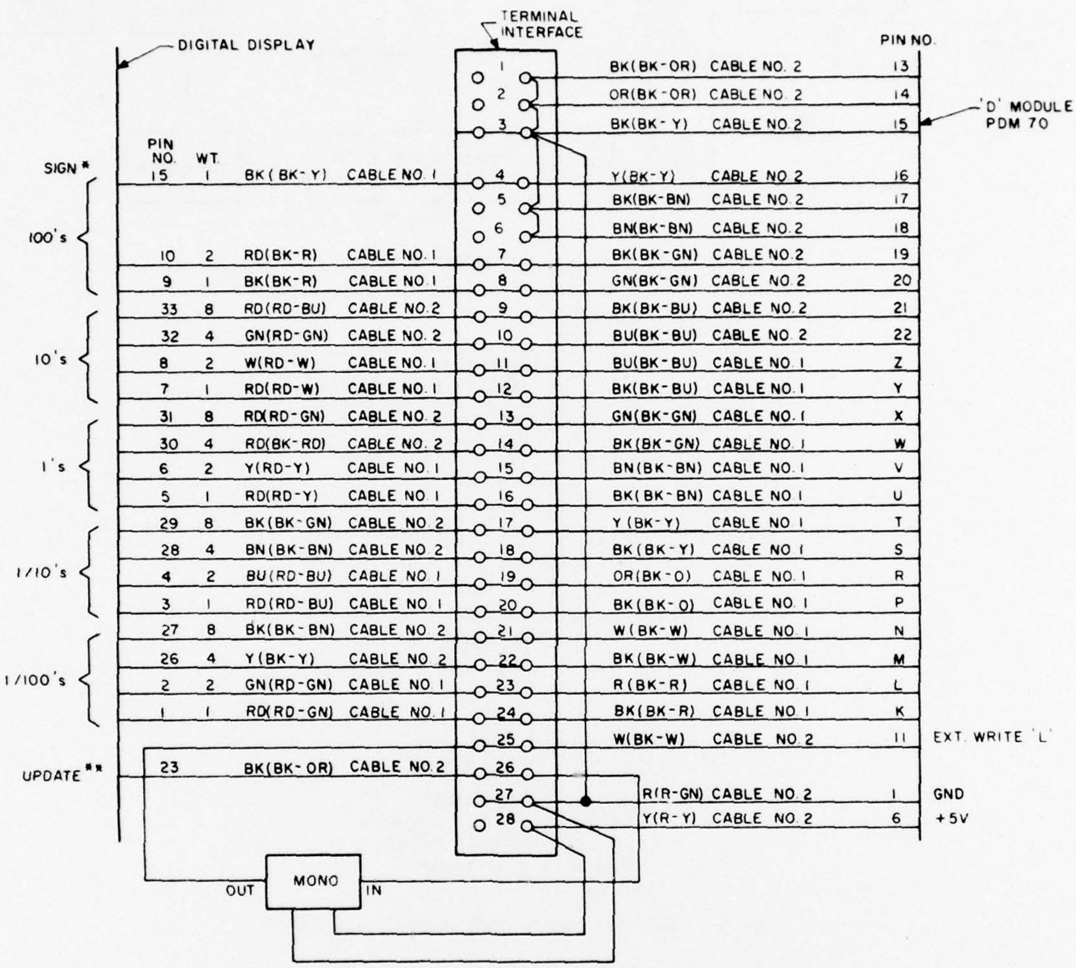
Fig. 40 — Character decode shaft angle display CAMS

hydrophone panel, Fig. 33. Also, the generated voltage and the hydrophone output voltage may be measured simultaneously on the new system.

## Pattern Measurement Subsystem

The hardware arrangement required to make pattern measurements is shown in Fig. 39.

The operator rotates the transducer by adjusting the rotator control. The response to the driven projector is measured on the SDVM as shown. This response voltage is converted to a BCD format for monitoring in the PDM 70 "D" module. Simultaneously, the rotator-servo drive motor turns the local turntable servomotor and also activates the display for the angle moved. The output of the shaft angle display is a one to five digit display plus sign with a resolution of 0.1 degree (See Figs. 40 and 41 for display decoding and encoding details.).




NOTES 1 SEE DWG E 1791 FOR DECODE DATA.

2 *1 = +

3 ** +5V, 1.25 Ms @ EACH UPDATE +5 0 (100 Hz)

4 *** TO PROVIDE A POS. TRIGGER TO STROBE DATA INTO PDM 70 WHEN DISPLAY UPDATE IS SETTLED, THE MONO DELAY (SEE DWG E 1792) CIRCUIT IS ADDED. THE BCD OUT - UPDATE RELATION IS AS FOLLOWS:

+5 = MARK
0 DATA

+5
0 UPDATE

**Fig. 41 — Shaft angle digital display interconnection to PDM 70 CAMS**

The angle data is then interfaced with the PDM 70 to be integrated with the response amplitude data. The computer receives the data from the PDM 70 as shown and displays the result back to the operator on the Tek-613 display in either polar or rectilinear form, as desired by the operator.

## PDM 70 Integration and Operating Subsystem

The operation of the PDM 70 data mover may be understood by referring to Figs. 6 and 18.

Basically the PDM 70 serves as the single point wherein data are converted from many forms and formats into a single standard serial ASCII format for communication with the computer. The communication is bidirectional, *i.e.*, the computer may command an instrument *via* the PDM 70 to perform a function, or the computer may just receive data sent to it from an instrument *via* the PDM 70. The proper interface encoding is done in the PDM 70.

There are four types of interface cards used in the PDM 70. These are:

32-bit input cards ("D" modules),
32-bit output cards ("E" modules),
Computer I/O card ("J" module),
Keyboard display card.

Each of the cards is assigned a position in the PDM 70 mainframe as shown in Figs. 6 and 18. Each of the cards is interfaced with its respective system hardware as shown in Fig. 6.

A 32-bit input card ("D" module) is shown interfacing to instruments which provide BCD output data such as the SDVM (see Fig. 12). The 4-bit BCD code for each voltage digit on the SDVM is connected to 4 bits of the 32-bit input card. The decoding of the total voltage format is shown in Fig. 11. With each voltage character decoded and interfaced with the "D" module, the PDM 70 may either take the data from the "D" module under command of its own internal clock (internal mode) or wait for an external pulse provided by the SDVM (see "Print Command" on Fig. 12), which arrives only when all measurement data are complete and ready for transfer (external mode).

The data are transferred from the input card to the common communication bus of the PDM 70. Data are taken from the common bus under control of the local PDM 70 clock and fed to the "J" module where these data are communicated to and from the computer in ASCII coded format.

Similarly, the 32-bit output card ("E" module) receives data from the "J" module which in turn communicates with the computer in serial ASCII format. Command data are transferred to the E card of interest (*via* address directive preceding the code command) where the command data are presented in BCD format to the interfacing hardware such as the SDVM (see Fig. 42). The SDVM Program input is interconnected to the "E" module as shown in Fig. 42 and represents encoded data shown in Fig. 10. Interconnection in this fashion permits the computer to directly command the SDVM to perform such functions as dB offset, control width of measurement gate, etc. Program executions are introduced by receipt from the computer of an "EOT" at the end of command message.

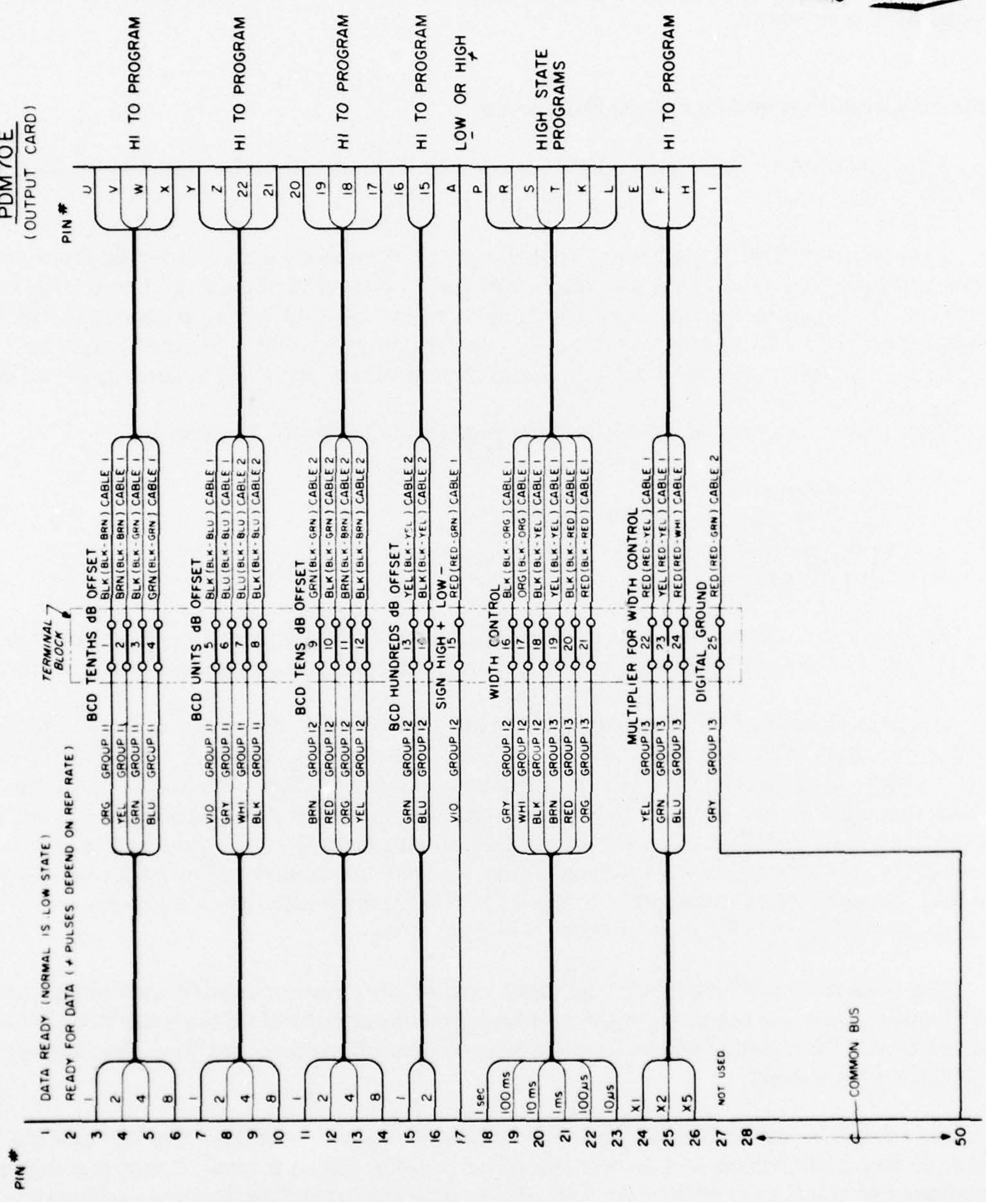



Fig. 42 — 1166 SDVM remote programming CAMS

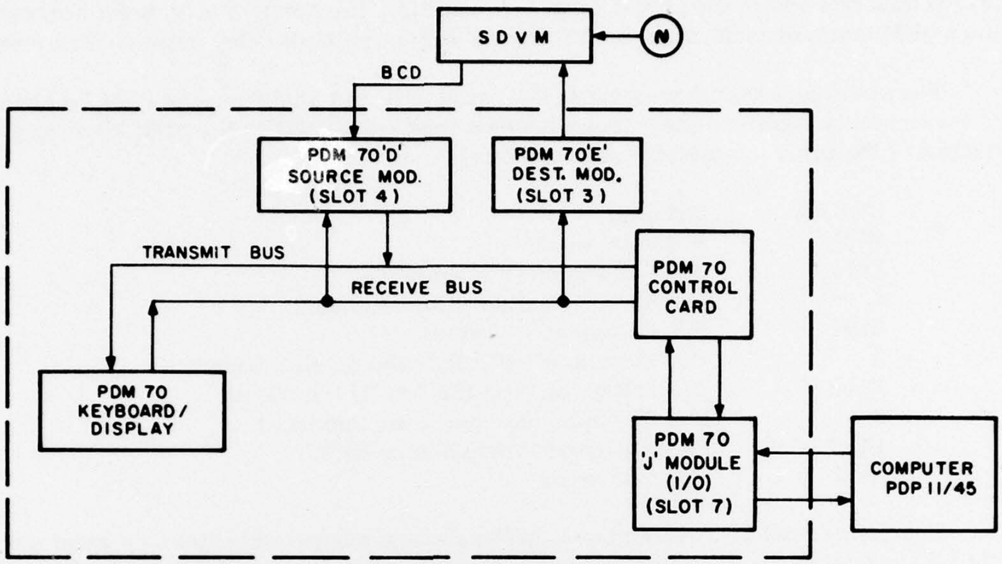



Fig. 43 — PDM 70 subsystem

The "J" module of the PDM 70 is used in ASCII for direct communications with the outside world. It both transmits data to the computer and receives data from the computer through its Universal Asynchronous Receive-Transmit (UART) chip. The clock rates for communication with the computer are selected on this "J" module. Data rates for this system are 1200 baud at this time; however, the 2400-baud rate is now being investigated as the more desirable communication speed.

The keyboard display card provides a means of inputting data onto the PDM 70 bus by direct input from the PDM 70 integral keyboard which contains a limited set of symbols and numbers. A local total system control may be exercised through use of the keyboard. Consider the typical subsystem shown in Fig. 43.

The process that occurs in transfer of displayed SDVM voltage numbers to the computer *via* the PDM 70 is given below.

The SDVM reads an input voltage and provides an output in digital BCD form to the "D" module as shown. In addition, the SDVM outputs a print command indicating that all data are ready for outputting. The "D" module, however, will ignore the input from the SDVM until it has been addressed and commanded by a program in the PDM 70 to take some action. The keyboard may be used to input a program to the control module which in turn commands the "D" module to transfer any input data onto the bus. The program may direct that no BCD input data be transferred onto the bus until the external signal print command is received (External Mode). The program may alternately direct that the BCD data be transferred onto the bus immediately (beginning with the next tick of the internal "System" clock). In either case, data from the "D" module will be transferred onto the PDM 70 bus where it will be fed to the "J" module for transmission to the computer at the

proper data rate and in the proper format. In addition, the program may direct how many of the SDVM measurements are to be transferred with or without delay between measurements.

For example, a simple program as follows may be initiated from the PDM 70 keyboard to continuously transfer voltage measurements from the SDVM to the PDM 70 display under control of the print command (External Mode).

| | |
|---|---|
| CLEAR | Bus clear |
| STX | Start text mode |
| DC 1 | Alert all source ("D") modules |
| 4 | Slot 4, "D" module, your command |
| SOH | Sub Command to follow |
| 3 | Ext. sync. mode (0,1,2,3) See maint. manual |
| DC 2 | Alert all destination ("E" or "J") modules |
| 0 | Slot 0, Display module, your command |
| DC 3 | Execute above Program after EXT |
| ETX | End text mode |

Depressing PDM 70 keyboard keys in the above sequence will enter a program into the PDM 70 and cause the SDVM voltage digits to be transferred to the PDM 70 display each time a print command is issued by the SDVM. The SDVM is typically operated in the external sync mode. In this mode, the toneburst generator will provide a trigger pulse at the start of the signal burst "on" interval which triggers the SDVM to take a measurement.

Similarly, the PDM 70 may be used as an instrument to remotely command a particular function of the SDVM (such as measurement gate width) as shown in Fig. 43 above. This requires programming into the PDM 70 to command the SDVM to measure with a specified gate width, as shown by the following program.

| | |
|---|---|
| CLEAR | Bus clear |
| STX | Start text mode |
| DC 1 | Alert all source (keyboard) modules |
| 0 | Keyboard slot, your command |
| DC 2 | Alert all destination ("E") modules |
| 3 | Slot 3, your command "E" module |
| 0 | Keyboard, display received characters |
| S1 | Literals for transfer follow |
| 0 | |
| 0 | |
| 0 | Literals to be sent to both slot 3 and display |
| 0 | modules |
| 8 | See Fig. 10 for encoding |
| 0 | (Sets up 1-ms meas. window) |
| 1 | |
| 0 | |
| DC 3 | Execute above after EXT |
| ETX | End text mode |

Execution of programs locally from the keyboard of the PDM 70 is extremely useful in a troubleshooting exercise to isolate any system failure. Data may be taken into each "D" module and displayed on the PDM 70 display for validation or equipment may be exercised with control functions transmitted out of each PDM 70 "E" module.

*Remote*

The remote mode of operating the PDM 70 is through its "J" module. In this system the computer is typically interfaced to the PDM 70 "J" module. The local Tek-4010 communications terminal is used to instruct the computer. The computer calls in a prepared program that may be, for example, the same as those shown above for local commands through the PDM 70 keyboard. The only exception is that the "J" module in slot 7 must now be properly used as source and destination modules.

A communications test mode has been designed into this system whereby errors that are suspected from the computer may be isolated from internal system errors. Fig. 2 (lower left) shows a system of connectors, located in the console, which may be interconnected in various ways. To check for communication errors, it is necessary only to interconnect the local terminal to the PDM 70. Both operate on ASCII format; however, at present the baud rates are different. Communication between the terminal and the computer goes on at 2400 baud, whereas communication between the PDM 70 and the computer is at 1200 baud. Therefore, if the connectors are jumpered from the terminal to the PDM 70 (1 or 2) it is also necessary to change the communication rate on the back of the terminal to 1200 baud. A program may now be communicated directly to the PDM 70 "J" module by simply typing instructions on the terminal keyboard.

For example, if it is desired to print out the SDVM measurements on the terminal, a simple program may be written to the PDM 70 "J" module as follows:

| Desired PDM 70 Program* | Tek-4010 Terminal Equivalent† |
|---|---|
| STX | ↑B |
| DC 1 | ↑Q |
| 4 | 4 |
| SOH | ↑A |
| 3 | 3 |
| DC 2 | ↑R |
| 0 | 0 |
| 7 | 7 |
| DC 3 | ↑S |
| ETX | ↑C |

*To start any program, first clear the PDM 70.
†↑ symbolizes the control key function on a keyboard.

This program will display SDVM measurements on both the PDM 70 display (slot location 0 following the DC 2) as well as on the screen of the Tek-4010 terminal. For optional programming possibilities, see *Logic Products — PDM 70 Users Maintenance Manual.* The total PDM 70 command vs teletype (TTY) keyboard function is as follows:

| | |
|---|---|
| DC 1 | ↑Q |
| DC 2 | ↑R |
| STX | ↑B |
| ETX | ↑C |
| DC 3 | ↑S |
| S1 | ↑0 |
| EOT | ↑D |
| DC 4 | ↑T |
| SOH | ↑A |
| SYN | ↑V |

**Integration and Operation of Synthesizer (Hewlet Packard No. 3330B)**

*Remote*

The synthesizer is somewhat unique in that additional status monitoring hardware has been added to indicate the mode of operation at all times—see Fig. 4. The HP 3330B synthesizer operates on the Hewlett Packard Interface Bus (HPIB) or IEEE Std. 75-488 concept. Communication with the synthesizer is accomplished *via* the "E" module of the PDM 70. As shown on Figs. 7 and 8, coded-data input signals are transmitted to the synthesizer from the PDM 70 by four parallel characters. The four parallel characters are developed from the 32-bit (4 bit per character) lines of the PDM 70 "E" module. In addition, the PDM 70 generates a coded input (fourth character, see Fig. 7) which notifies the synthesizer whether the subsequent code to be sent is an address or function code. It is necessary when communicating with the synthesizer to provide an address code, followed by a function code. Once the address of the synthesizer has been sent, the synthesizer will listen to subsequent commands such as frequency select to be transmitted subsequently. A listing of the coded commands that may be sent are given in the System Components section of this report under HP Synthesizer. An analog frequency response plot is obtainable from the SDVM by interconnecting from the patch board the SDVM analog to the X-Y recorder Y-channel and the analog of the synthesizer to the X-channel. This permits plotting directly on selected graph paper. It should be noted here that the frequency plot X-drive from the synthesizer is a digitally stepped ramp function of 0-10 V over the selected frequency sweep range.

*Local*

Operation in the local mode is very simple. A local-remote switch near the HPIB Status LED must be placed in the local position. The procedure then is to depress the frequency button on the synthesizer keyboard, followed by the frequency digits desired, followed by the magnitude multiplier (Hz, kHz, MHz, etc.). The procedure is repeated for amplitude. If it is desired to sweep a frequency range, the center frequency (midway between the start and stop frequency) in midrange is initially punched in as a frequency of operation. Next,

the number of steps and frequency per step are depressed. For example, if the frequency range to be swept is 10 to 30 kHz and it is desired to sweep the range in 1000 steps, then the 1000-step key is selected. This calls for a center frequency of 20 kHz and a frequency per step of 20 Hz. The setup may be checked before starting by selecting the sweep up position key, depressing first point key, selecting sweep down position, and depressing again the first point key. The start and stop frequencies will be displayed on the synthesizer LEDs at the respective key positions.

The system is arranged so that the synthesizer output is maintained at a rather high level (approximately +0 dBm) and thus insure that the toneburst generator will always have a strong enough signal to fire "on" and "off" with. The output of the toneburst generator is provided with two 10-step attenuators in series—one of 10 dB per step and the other of 1 dB per step. However, it is possible to get 0.1 dB attenuation adjustment instead of these preselected values by punching in 0.1 dBm changes directly on the synthesizer. Figure 2 indicates the various interconnections of the synthesizer that are possible in the system.

**Integration and Operation of SDVM (Scientific Atlanta No. 1166)**

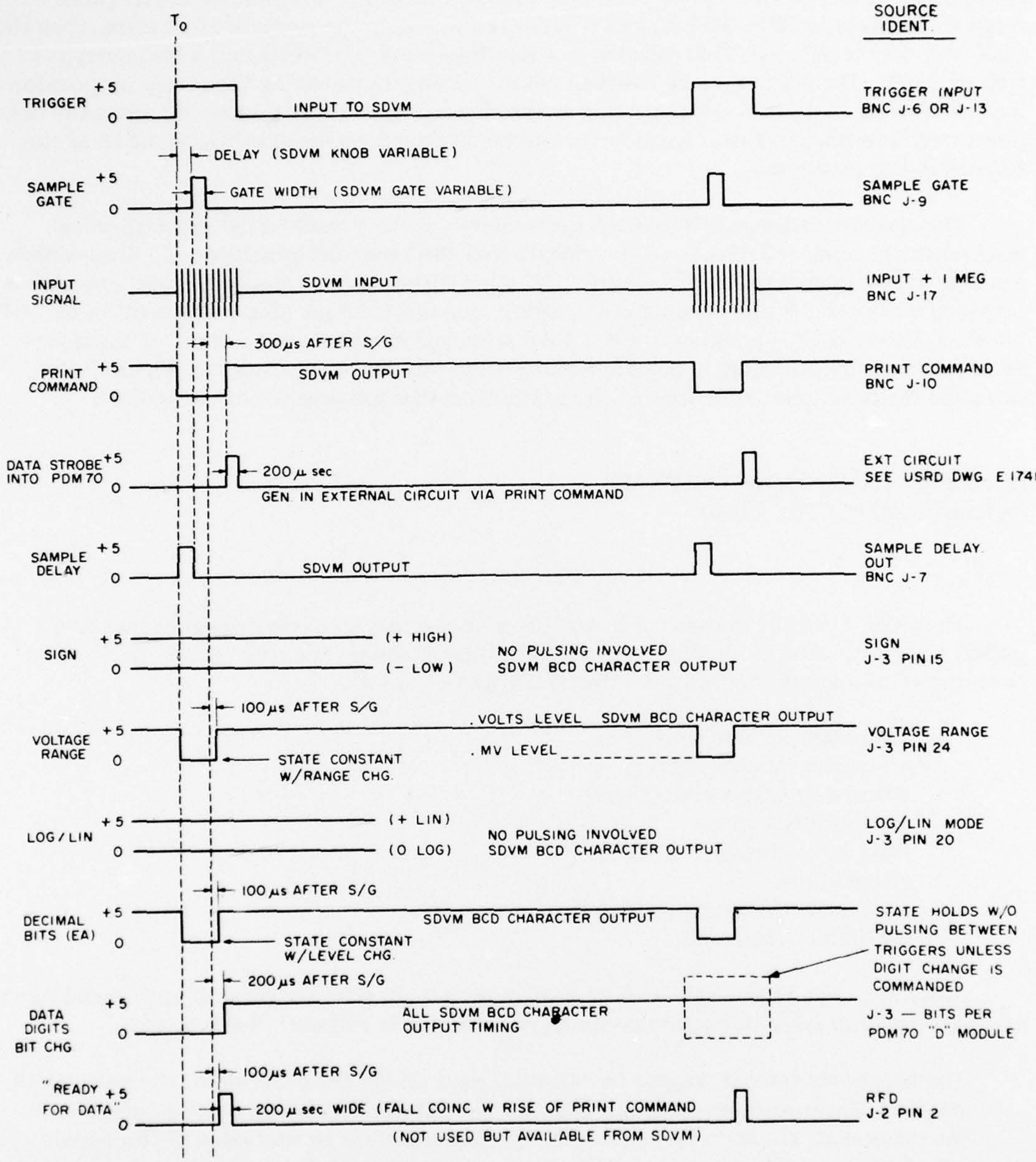
*Local*

The SDVM used in the system is capable of measuring true rms or peak values of a pulsed waveform. The mode of selection is by push-button on the front panel. In addition to this type of measurement, other selectable parameters are:

measurement gate width,
measurement gate delay,
internal or external triggering,
input impedance,
filter frequencies,
attenuation,
log/linear measurement, and
dB offset in log mode.

Assuming (1) a pulsed sine wave as a signal input, (2) a trigger pulse at each signal burst, and (3) operation set to the external mode, operation is as follows: (See Fig. 44.)

The trigger arrives and triggers the measurement on for the duration of the pulsewidth selected. The measurement gate is delayed from the trigger by an amount selected on the delay dial. The measurement detector measures peak or rms value of the signal waveform according to the selected measurement mode only during the gated interval. The measured value is displayed on the front panel nixie display along with appropriate scale and mode factors such as mV or V on the linear scale or dB *re* 1 V on the log scale. An offset reference of the measured value may be selected on the log mode by proper positioning of the offset thumbwheels.




NOTE: A HIGH TO LOW TRANSITION LOADS DATA INTO PDM 70 "D" MODULE

**Fig. 44 — SDVM output timing diagram CAMS**

*Remote*

Operation in the remote mode is controlled by the PDM 70 *via* its "E" and "D" modules. Function codes are sent out to the SDVM to set up the above functions through the "E" module in slot 4 of the PDM 70. Data in the form of the voltage digits displayed are sent out of the instrument to the PDM 70 *via* the "D" card interface. These interconnections and corresponding encode and decode data sheets are given in Figs. 12, 10, and 11.

Data may be brought out of the SDVM *via* the PDM 70 by a simple test program as follows, executed on the PDM 70 keyboard:

STX
DC 1
4
DC 2
SOH
3
DC 3
ETX

The same data may be sent to the computer or any device interfaced with the PDM 70 "J" module by adding the card location 7 for the "J" module in the code just after the DC 2.

Similarly, a simple program may be written to remotely set up the SDVM sample gate width at 1 ms *via* the computer as follows:

STX
DC 1
7
DC 2
4
SI
0
0
0
0
8
0
1
0
DC 3
ETX

The meaning of each of the coded input commands is as described in the PDM 70 portion of this report (or see the PDM 70 Users Manual).

**Integration and Operation of the Digital Scope (Nicolet No. 1090)**

*Local*

The digital scope is utilized to digitize analog current and voltage waveforms prior to transmission to the computer for processing. Input signal data are patched into either or both of the two channels from the patch panel. Typically, one channel will be for voltage and the other for current. The interconnection of the scope is shown in Figs. 2 and 15 for remote-control signal interconnection. The trigger input is typically from the toneburst generator sync output (coherent with the burst "on" interval). The digital scope has been modified at the factory so that Pin 1 of the front panel connector makes available an output clock of 1-MHz synchronous with the scope's 20-MHz clock for phase lock purposes with the other system synthesizers.

A typical measurement will have a sine signal applied to each channel simultaneously for phase measurements. The scope is operated in the external mode, wherein adjustment of the trigger level is required to assure continuous triggering and updating of information into the scope memory. The sweep time per point and multiplier are adjusted for the desired sampling profile. The two-channel sine data will be displayed on the screen similar to the analog scope. Cursors (horizontal and vertical) are provided, whereby any desired portions of the scope screen may be expanded for closer inspection. Once a portion of the signal waveforms has been selected and expanded (if desired), the displayed data may be held for transmission to the computer or other peripheral by depressing the hold-last or hold-next button. This essentially freezes the data in memory either from the last trigger or from the next trigger. The data may now be transmitted out the back connector to the computer by depressing the I/O execute button on the scope face. The output data will be a voltage level for each sampled point that is displayed. The data word is a 12-bit binary number representing the position of the sampled point on the display (or in memory). See Fig. 17 for a detailed breakdown of the data decoding.

*Remote*

The remote operation control is the output mode, hold last, hold next, and the remote I/O which are specifically identified in Figs. 15 and 7. In this mode, it is assumed that the operator will initially set up the desired data for transmission prior to resorting to the remote mode.

## SYSTEM PERFORMANCE VERIFICATION AND CALIBRATION

The details of the system for calibration purposes are shown in Fig. 32. A simplified version of the system for checkout and calibration purposes is shown in Fig. 45.

Figure 45 indicates the system interconnections for performance-verification testing of the system. The basic concept for testing the transmit portion is to initially establish a set of drive conditions that fix nominal levels across the standard load as shown. The true voltage level across the standard may be determined on a point-by-point basis across the frequency spectrum of interest. A comparison of future measurements with the initial data will give a

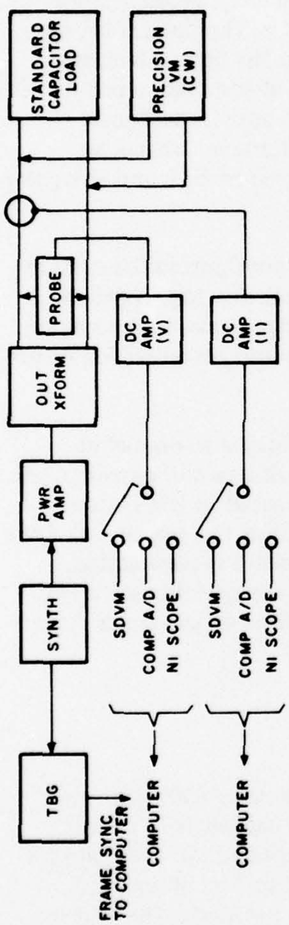



Fig. 45a — Transmit verification test

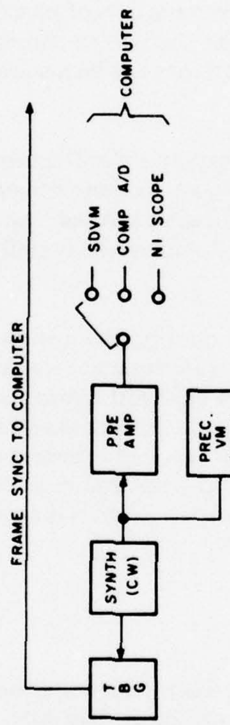



Fig. 45b — Receive verification test

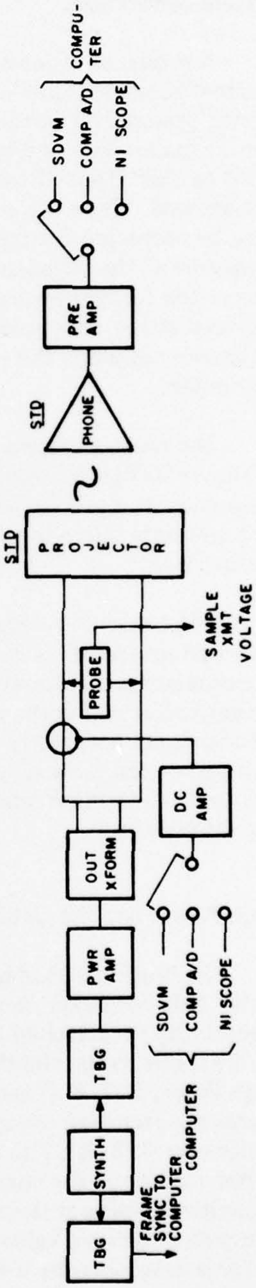



Fig. 45c — Transmit/receive calibration

quick indication of changes in system transmit characteristics. It will be noted that a voltage and current pickoff at the load is processed through amplifiers and measured by several devices. These measurements also need to be compared with the true load values to establish system calibration.

A means of accurately calibrating the system *via* the on-line computer, such that subsequent measurements of load impedance may be made, is also suggested by the aforementioned system test concept. Since the standard capacitor is accurately known in value and can be made close to a pure reactance (a complete line of standard capacitors is being developed to USRD specifications for this purpose), then the load current may be accurately determined. When these analog samples of load E and I are returned to the computer, they may be corrected for transmission loss by inputting to the computer the true values as measured at the standard. Since the E and I relative phase is known at the load, a proper correction factor may be made for any variation of phase between E and I waveforms received at the computer to correct for the known standard 90° difference. Hence, an unknown replacing the standard capacitor may be accurately measured in E, I, and Ø by the computer.

The receive system may be performance-verification tested by configuring the system as shown in Fig. 45. Again in this case, an accurate system synthesizer develops a precise frequency at a precise level for transmission through the receive components of the system. The response curve for the receive system may be initially measured and recorded for future comparison.

The transmit/receive calibration configuration shown in Fig. 45(c) is a somewhat standard means of calibrating the entire system at one time. Here, voltages and currents into the standard projector are recorded. A standard hydrophone is connected to the system preamp after which the responses may be measured and recorded. Since the responses of the standards are accurately known, variations from these standards indicate system status. Also, of course, this same procedure may be used in a comparison type of calibration procedure to determine relative characteristics of an unknown hydrophone or projector replacing the standards.

**High-Power System Calibration**

Calibration of the high-power system is accomplished in conjunction with the computer A/D converter on a point-by-point basis. Basically, a standard capacitor (with full traceability) is attached to the output of the power amplifier. Voltage and current samples of the input to the standard capacitor are taken as previously shown in Fig. 36 entitled High Power E, I, & Ø monitor instrumentation. While operating in a cw mode, the voltage across the standard capacitor is measured with a precision calibrated voltmeter (0.1% Fluke Voltmeter #931B). The computer samples the voltage waveform and is given the Fluke voltmeter reading as the corresponding reference level. The computer is also given the standard capacitance value measured accurately and calibrated to four places. From these data the computer derives a value of current. The current signal waveform that is sent to the computer is developed by a Pearson transformer around the standard capacitor load line. The computer thus has the reference-waveform level for which the computed current applies.

The standard capacitor represents what is considered to be the best known practical device with which to measure and control self characteristics. The only uncontrolled parameter of particular interest in the capacitor is the dissipation factor (tangent of the loss angle). The dissipation factor is measured and given to the computer as a known correction factor to be used by the computer to define the final calibration component—phase. The phase angle between the voltage and current waveform, using the standard capacitor as a load to the amplifier, may cause any phase angle to be generated at the computer end, depending on other system characteristic which will affect measured phase angle. The resulting angle will be generated by the standard capacitor (-90° + angle loss due to dissipation factor of the capacitor) as well as any phase shifting attributed to the transmission of the signal waveforms to the computer. The computer will accurately measure the E and I phase relation existing with the standard capacitor as load and will then assign to that reference the real value of -90°. Hence, the computer has stored the reference corrections for voltage, current, and phase relations in subsequent measurements.

A similar procedure may be used to calibrate the low-power portion of the system.

## CONCLUSIONS

The hardware implementation task has been completed, and even at this early stage the computerized measuring concept has shown a considerable number of advantages over the conventional measuring techniques. Some of the more important advantages are:

- The general ability of the computerized system to accurately measure voltage, current, and phase characteristics of underwater projectors as well as receiving hydrophone voltage, and to combine these parameters as necessary through programming to support major measurement types such as comparison calibrations, reciprocity calibrations, free-field voltage sensitivity, transmitting current response, transmitting voltage response, and pattern measurements, etc.,

- Ability to compute E, I, and $\phi$ drive parameters accurately through computer analysis of distorted waveforms, thus providing accurate dynamic measurements of source immittance,

- Real-time feedback of computed "final curves" for the spot analysis, and

- Computerized labor-saving data reduction with uniform report format.

In general, operation of the system requires close cooperation between the measurement and software groups to assure simple yet complete programs with adequate flexibility. This mutual assistance concept is working well and results in a considerable time saving of the overall measurement task with accurate traceability and reproducible results.

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